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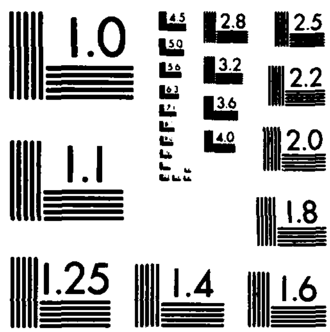

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DEPARTMENT OF TRANSPORTATION

COAST GUARD

COMMANDANT'S INTERNATIONAL TECHNICAL SERIES

VOLUME IV

Regulations on Subdivision and Stability of Passenger Ships as Equivalent to Part B of Chapter II of the INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

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Regulations and a set of explanatory notes written by the Subcommittee on Subdivision and Stability of the Intergovernmental Maritime Consultative Organization (IMCO)

16. Abstract

This report contains ~~The documents attached concern~~ a new equivalent system of international regulations on the subdivision of passenger ships, adopted in November 1973 by the Assembly of the Intergovernmental Maritime Consultative Organization (IMCO). These new regulations are considered an alternative to the provisions of the 1960 Convention on the Safety of Life at Sea.

This system of regulations is the result of 12 years of study internationally by the IMCO Subcommittee on Subdivision and Stability, in which some 20 countries participated. Based on probability principles, this new system focuses directly upon the ability of a ship to survive damage. It imposes fewer constraints upon design and will permit the Coast Guard as the U. S. maritime safety agency to be responsive to novel hull arrangements.

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THE COMMANDANT OF THE UNITED STATES COAST GUARD
WASHINGTON 20590

11 April 1974

TO UNITED STATES MARITIME INTERESTS:

SUBDIVISION AND STABILITY OF PASSENGER VESSELS

The documents attached concern a new equivalent system of international regulations on the subdivision of passenger ships, adopted in November 1973 by the Assembly of the Inter-governmental Maritime Consultative Organization (IMCO). These new regulations are considered an alternative to the provisions of the 1960 Convention on the Safety of Life at Sea.

This system of regulations is the result of 12 years of study internationally by the IMCO Subcommittee on Subdivision and Stability, in which some 20 countries participated. Based on probability principles, this new system focusses directly upon the ability of a ship to survive damage. It imposes fewer constraints upon design and will permit the Coast Guard as the U. S. maritime safety agency to be responsive to novel hull arrangements.

The text attached and the explanatory notes I commend to your attention in the interest of Maritime Safety. A professional paper now under development for possible presentation to the Society of Naval Architects and Marine Engineers will develop in greater detail the application of these new rules.

Toward our common goal of safety at sea,

C. R. Bender

C. R. BENDER
Admiral, U. S. Coast Guard

INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION

ASSEMBLY - 8th session
Agenda item 10

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RESOLUTION A.265(VIII)

adopted on 20 November 1973

REGULATIONS ON SUBDIVISION AND STABILITY OF PASSENGER SHIPS AS EQUIVALENT TO PART B OF CHAPTER II OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

THE ASSEMBLY,

NOTING Article 16(i) of the Convention on the Inter-Governmental Maritime Consultative Organization concerning the functions of the Assembly,

NOTING ALSO Recommendation 6 of the International Conference on Safety of Life at Sea, 1960,

BEARING IN MIND Regulation 5 of Chapter I of the International Convention for the Safety of Life at Sea, 1960,

HAVING CONSIDERED the Recommendation of the Maritime Safety Committee at its twenty-seventh session on the adoption of Regulations on Subdivision and Stability of Passenger Ships as an equivalent to Part B of Chapter II of that Convention and consequential changes to other Parts of that Chapter, as well as explanatory notes to the aforementioned Regulations prepared by the Sub-Committee on Suvdivision and Stability, which have been circulated to governments in MSC/Circ.153 for guidance and information,

RECOMMENDS that governments concerned accept the total application of the Regulations on Subdivision and Stability of Passenger Ships set out in the Annex to this Resolution as being equivalent to and a total alternative to the provisions of Part B of Chapter II of the International Convention for the Safety of Life at Sea, 1960,

INVITES governments, through the Organization, to exchange information on the action taken in this respect,

RECOMMENDS that governments, through the Organization, should exchange experience gained as a result of using these Regulations, particularly in regard to the use of such relaxations which are permitted by Regulation 2(d),

REQUESTS the Maritime Safety Committee to consider comments submitted as a result of the application of these Regulations with a view to practical evaluation of the Regulations and determining their suitability and related necessary changes to Chapter II of that Convention, as amendments to that Chapter.

ANNEX

REGULATIONS ON SUBDIVISION AND STABILITY OF PASSENGER SHIPS AS AN EQUIVALENT TO PART B OF CHAPTER II OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

1. The Regulations hereunder constitute an equivalent to and a total alternative to the requirements of Part B of Chapter II of the International Convention for the Safety of Life at Sea, 1960 for passenger ships.

2. In applying these equivalent Regulations the following should be observed for other Parts of Chapter II of that Convention:

Part A Regulation 1(d) and Regulation 2 are not applicable.

Parts C, F and H

In Regulations 25(a), 37(b), 68(a), 94(1), 96(b), 99(a), (b) and (c) and 108 the term "bulkhead deck" is to be replaced by the term "relevant bulkhead deck" as defined in Regulation 1(e) of the equivalent Regulations.

3. The following references to Regulations relate solely to the Regulations of this Equivalent.

Regulation 1 – Definitions

For the purpose of these Regulations, unless expressly provided otherwise:

(a) (i) A "subdivision loadline" is a waterline used in determining the subdivision of the ship; and

(ii) the "deepest subdivision loadline" is the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable.

(b) the "subdivision length of the ship" (L_s) is the extreme moulded length of that part of the ship below the immersion limit line.

(c) "midlength" is the midpoint of the subdivision length of the ship (L_s).

(d) (i) the "breadth" (B_1) is the extreme moulded breadth of the ship at midlength at or below the deepest subdivision loadline;

(ii) the "breadth" (B_2) is the extreme moulded breadth of the ship at midlength at the relevant bulkhead deck.

(e) The "relevant bulkhead deck" is the uppermost deck which, together with the watertight bulkheads bounding the extent of flooding under consideration and the shell of the ship, defines the limit of watertight integrity in the flooded condition.

(f) The "immersion limit line" at any point in L_s is defined by the highest relevant bulkhead deck at side at that point.

(g) The "draught" (d_i) is the vertical distance from the moulded base line at midlength to the waterline in question.

(i) The "subdivision draught" (d_s) is the draught up to the subdivision loadline in question.

(ii) The "lightest service draught" (d_o) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

(iii) Intermediate draughts between d_s and d_o are:

$$d_1 = d_s - \tfrac{2}{3}(d_s - d_o)$$

$$d_2 = d_s - \tfrac{1}{3}(d_s - d_o)$$

$$d_3 = d_s - \tfrac{1}{6}(d_s - d_o)$$

(h) The "effective mean damage freeboard" (F_1) is equal to the projected area of that part of the ship taken in the upright position between the relevant bulkhead deck and the damage waterline and between $\frac{1}{3}L_s$ forward and abaft the midlength divided by $\frac{2}{3}L_s$. In making this calculation no part of the area which is more than $0.2B_2$ above the damage waterline shall be included. However, if there are stairways or other openings in the bulkhead deck through which serious downflooding could occur F_1 shall be taken as not more than $\frac{1}{3}(B_2 \tan \theta_f)$, where θ_f is the angle at which such openings would be immersed.

(i) The "permeability" (μ) of a space is the proportion of the immersed volume of that space which can be occupied by water.

Regulation 2 – Subdivision Index

(a) To provide for buoyancy and stability after collision or other damage, ships shall have sufficient intact stability and be as efficiently subdivided as is possible having regard to the nature of the service for which they are intended.

(b) The subdivision of a ship is considered sufficient if:

(i) the stability of the ship in damaged condition meets the requirements of Regulation 5; and

(ii) the attained Subdivision Index A according to Regulations 6 and 7 is not less than the required Subdivision Index R calculated in accordance with paragraph (c) of this Regulation.

(c) The degree of subdivision is determined by the required Subdivision Index R, as follows:

$$R = 1 - \frac{1000}{1.22L_s + N + 1500} \quad \text{(in feet)}$$

$$\dots\dots\dots\dots\dots \text{(I)}$$

$$R = 1 - \frac{1000}{4L_s + N + 1500} \quad \text{(in metres)}$$

Where:

$N = N_1 + 2N_2$

N_1= number of persons for whom life-boats are provided.

N_2= number of persons (including officers and crew) that the ship is permitted to carry in excess of N_1.

(d) Where the conditions of service are such that compliance with paragraph (b) of this Regulation on the basis of $N = N_1 + 2N_2$ is impracticable and where the Administration considers that a suitably reduced degree of hazard exists, a lesser value of N may be taken but in no case less than $N = N_1 + N_2$.

Regulation 3 – Special Rules concerning Subdivision

(a) In ships 330 feet (or 100 metres) in length and upwards the watertight transverse bulkhead next abaft the forepeak bulkhead shall be located so that the s-value, as defined in Regulation 6(a), for a combination of the forepeak and adjacent compartment, calculated by formulae (VIII) and (IX) shall not be less than 1.0. However, in no case shall the distance between the forepeak bulkhead and the next bulkhead be less than the longitudinal extent of damage specified in Regulation 5(b)(i).

(b) A watertight transverse bulkhead may be recessed provided that all parts of the recess lie inboard of vertical surfaces on both sides of the ship, situated at a distance of $0.2B_1$ from the ship's side, and measured at right angles to the centreline at the level of the subdivision loadline. Any part of a recess which lies outside these limits shall be dealt with as a step, as provided in Regulation 5(b)(i).

Regulation 4 – Permeability

(a) For the purpose of the subdivision and damage stability calculations of Regulations 5, 6 and 7 the permeability of each space or part of a space subject to flooding either during any intermediate stage or in the final stage of flooding shall be as follows:

Spaces	*Permeability* (μ)
Appropriated as accommodation for passengers and crew, or other spaces not specifically herein designated	0.95
Appropriated for machinery	0.85
Normally occupied by stores	0.60
Intended for consumable liquids	0.00 or 0.95*

* whichever results in the more severe requirement.

(b) The permeability μ of any space appropriated for cargo shall be assumed to vary with the draught before damage in such a way that for any initial draught d_i the permeability μ_i of any cargo space shall be taken as:

$$\mu_i = 1.000 - \frac{1.2(d_i - d_o)}{d_s} - \frac{0.05(d_s - d_i)}{(d_s - d_o)}$$

but not more than 0.95 nor less than 0.60.

(c) If the ship's arrangement or service are such that the use of other permeabilities resulting in more severe requirements is logical the use of other permeabilities may be required by the Administration.

Regulation 5 – Subdivision and Damage Stability

(a) Sufficient intact stability shall be provided in all service conditions so as to enable the ship to comply with the provisions of this Regulation. Before certification of the ship the Administration shall be satisfied that the required intact stability can practicably be obtained in service.

(b) (i) All ships shall be so designed as to comply with the provisions of this Regulation in the event of flooding due to one side damage with a penetration of $0.2B_1$ from the ship's side at right angles to the centreline at the level of the subdivision loadline and a longitudinal extent of 9.8 feet (3.00 metres) + $0.03L_s$, or 36 feet (11 metres) whichever is the less, occurring anywhere in the ship's length, but not including a transverse bulkhead. However, where a bulkhead is stepped it shall be assumed as subject to damage.

(ii) Ships for which N is more than 600 shall additionally be able to comply with this Regulation in the event of flooding, due to side damage including transverse bulkheads occurring anywhere within a length equal to $(\frac{N}{600} - 1.00)L_s$, measured from the forward terminal of L_s, where N is as defined in Regulation 2(c) and (d). The value of $(\frac{N}{600} - 1.00)$ shall not be more than one.

(iii) In any calculation required under this paragraph the damage shall be assumed to extend from the base line upwards without limit. However, if flooding due to a lesser extent of damage either vertically, transversely or longitudinally results in a higher necessary intact metacentric height, such a lesser extent of damage shall be assumed. In all cases, however, only one breach in the hull and only one free surface need be assumed. For the purpose of assessing heel prior to equalization the bulkheads and deck bounding refrigerated spaces and other decks or inner divisions which in the opinion of the Administration are likely to remain sufficiently watertight after damage, shall be regarded as limiting flooding. Otherwise, flooding shall be assumed as limited only by undamaged watertight structural divisions.

(c) (i) In the final stage of flooding:

(1) there shall be a positive metacentric height, GM, calculated by the constant displacement method and for the ship in upright condition, of at least

$$GM = 0.003 \frac{B_2{}^2(N_1 + N_2)}{\Delta F_1} \quad \text{or}$$

$$GM = 0.049 \frac{B_2}{F_1} \quad \text{(in feet)}$$

$$GM = 0.015 \frac{B_2}{F_1} \quad \text{(in metres)} \quad \text{or}$$

GM = 2 inches (0.05 m) whichever is the greater

Where Δ = displacement of the ship in the undamaged condition (in long tons or metric tons respectively);

(2) the angle of heel in the case of one compartment flooding shall not exceed 7 degrees. For the simultaneous flooding of two or more adjacent compartments a heel of 12 degrees may be permitted unless the Administration considers a lesser heel necessary to ensure an adequate amount and range of residual stability;

(3) except in way of the flooded compartment or compartments no part of the relevant bulkhead deck at side shall be immersed.

(ii) Unsymmetrical flooding shall be kept to a minimum consistent with efficient arrangements. If any equalizing arrangements are necessary to ensure that the angle of heel in the final stage of flooding does not exceed the limits specified in sub-paragraphs (i)(2) and (3) of this paragraph, these arrangements shall, where practicable, be self-acting. However, if controls are necessary, they shall be operable from above the highest relevant bulkhead deck. All such arrangements shall be acceptable to the Administration.

(iii) The Administration shall be satisfied that stability prior to equalization is sufficient. However, in no case shall the maximum heel before equalization exceed 20 degrees nor shall it result in progressive flooding. Additionally, the time for equalization of cross-connected spaces to at least the limits specified in sub-paragraphs (i)(2) and (3) of this paragraph shall not exceed ten minutes.

(iv) The Administration shall be satisfied that the residual stability is sufficient during intermediate flooding and that progressive flooding will not take place. Calculations relative thereto shall be in accordance with the provisions of sub-paragraph (b)(iii) of this Regulation, respecting the assumed extent of damage and resulting extent of flooding. Heel during intermediate flooding due either to negative metacentric height alone or in combination with unsymmetrical flooding shall not exceed 20 degrees.

(d) Damage stability calculations performed in compliance with this Regulation shall be such as to take account of the form and the design characteristics of the ship and the arrangements, configuration and probable contents of the compartments considered to be flooded. In making calculations for heel prior to equalization and for equalization time, the flooding of that portion of the ship opened to the sea shall be assumed to be completed prior to commencement of equalization. For each initial draught condition the ship shall be at the most unfavourable intact service trim anticipated at that draught having regard to the influence of the trim on the freeboard in the flooded condition.

(e) The intact metacentric height, and corresponding vertical centre of gravity, necessary to provide compliance with the requirements specified in paragraphs (b) and (c) of this Regulation shall be determined for the operating range of draughts between d_s and d_o. If (d_s-d_o) does not exceed 0.1 d_s, damage stability calculations may be made only for d_s and d_o, and the intermediate values may be obtained by linear interpolation. If (d_s-d_o) exceeds 0.1 d_s, damage stability calculations shall also be made for at least one additional intermediate draught. However, in all cases where there are vertical discontinuities in permeabilities or in free surfaces which may result in discontinuities in the necessary intact metacentric height, damage stability calculations shall be made for the corresponding draughts in order to define such discontinuities.

Regulation 6 – Attained Subdivision Index A

(a) (i) In addition to complying with Regulation 5 the attained Subdivision Index A shall be determined for the ship by formula (II):

$$A = \Sigma\, aps \quad \text{.............................(II)}$$

Where:

"a" accounts for the probability of damage as related to the position of the compartment in the ship's length,

"p" evaluates the effect of the variation in longitudinal extent of damage on the probability that only the compartment or group of compartments under consideration may be flooded, and

"s" evaluates the effect of freeboard, stability and heel in the final flooded condition for the compartment or group of compartments under consideration.

(ii) The summation indicated by formula (II) is taken over the ship's length for each compartment taken singly. To the extent that the related buoyancy and stability in the final condition of flooding are such that "s" is more than zero, the summation is also taken for all possible pairs of adjacent compartments, and may be taken for all possible groups of a higher number of adjacent compartments if it is found that such inclusion contributes to the value of the attained Subdivision Index A.

(iii) Wherever wing compartments are fitted and where the assumed damage used in the damage stability calculations according to Regulation 5 forming the basis for the "s" calculation does not result in flooding of the associated inboard spaces, "p" shall be multiplied by "r" as determined in Regulation 7(b).

(b) The factor "a" in formula (II) shall be determined for each compartment and for each group of compartments by formula (III):

$$a = 0.4\left[1 + \xi_1 + \xi_2 + \xi_{12}\right] \qquad \text{(III)}$$

Where

$$\xi_1 = \frac{X_1}{L_s} \text{ if } X_1 \text{ is equal to or less than } 0.5L_s$$

and otherwise

$$\xi_1 = 0.5$$

$$\xi_2 = \frac{X_2}{L_s} \text{ if } X_2 \text{ is equal to or less than } 0.5L_s$$

and otherwise

$$\xi_2 = 0.5$$

$$\xi_{12} = \frac{X_1 + X_2}{L_s} \text{ if } X_1 + X_2 \text{ is equal to or less than } L_s$$

and otherwise

$$\xi_{12} = 1.0$$

and where

X_1 = the distance from the aft terminal of L_s to the aft end of the considered compartment or group of adjacent compartments;

X_2 = the distance from the aft terminal of L_s to the forward end of the considered compartment or group of adjacent compartments.

For purposes of this paragraph and of paragraph (c) of this Regulation, with respect to the length of any compartment or groups of compartments under consideration, where one or both of the limiting bulkheads have steps, the forward and after ends of the considered compartment or group of compartments shall be taken at the portions of the bulkheads which are nearest to each other.

(c) The factor "p" in formula (II) shall be determined for each compartment and for each group of compartments by formulae (IV) – (VII).

(i) In general, "p" shall be:

$$p = W\left[4.46\left(\frac{\ell}{\lambda}\right)^2 - 6.20\left(\frac{\ell}{\lambda}\right)^3\right] \text{ for } \frac{\ell}{\lambda} \text{ equal to } 0.24 \text{ or less}$$

and otherwise,

$$p = W\left[1.072\frac{\ell}{\lambda} - 0.086\right] \qquad \text{(IV)}$$

Where

ℓ = the length of compartment or group of compartments as defined in paragraph (b) of this Regulation

W = 1.0 and $\lambda = L_s$ for L_s = 655 feet (200 metres) or less

and otherwise,

$$W = \frac{602.5}{L_s - 52.5} \text{ and } \lambda = 655 \text{ (for } L_s \text{ in feet)}$$

$$W = \frac{184}{L_s - 16} \text{ and } \lambda = 200 \text{ (for } L_s \text{ in metres)}$$

(ii) To evaluate "p" for compartments taken singly, formulae (IV) are applied directly.

(iii) To evaluate the "p" values attributable to groups of compartments, the following supplementary nomenclature and formulae apply:

$\ell_1, \ell_2, \ell_3, \ell_4$, etc. are the lengths of compartments taken singly

$\ell_{12}, \ell_{23}, \ell_{34}$, etc. are the lengths of pairs of adjacent compartments

ℓ_{123}, ℓ_{234}, etc. are the lengths of groups of three adjacent compartments

ℓ_{1234}, etc. is the length of a group of four adjacent compartments

p_1, p_2, p_3, p_4, etc. are p calculated by formulae (IV) using $\ell_1, \ell_2, \ell_3, \ell_4$, etc. as ℓ.

p_{12}, p_{23}, p_{34}, etc. are p calculated using $\ell_{12}, \ell_{23}, \ell_{34}$, etc. as ℓ.

p_{123}, p_{234}, etc. are p calculated using ℓ_{123}, ℓ_{234}, etc. as ℓ.

p_{1234}, etc. is p calculated using ℓ_{1234}, etc. as ℓ.

For compartments taken by pairs.

$$\left.\begin{array}{l} p = p_{12} - p_1 - p_2 \text{ or} \\ p = p_{23} - p_2 - p_3 \text{, etc.} \end{array}\right) \quad \ldots\ldots\ldots\ldots \quad \text{(V)}$$

For compartments taken by groups of three,

$$\left.\begin{array}{l} p = p_{123} - p_{12} - p_{23} + p_2 \text{, or} \\ p = p_{234} - p_{23} - p_{34} + p_3 \text{, etc.} \end{array}\right) \quad \ldots\ldots\ldots\ldots \quad \text{(VI)}$$

For compartments taken by groups of four,

$$p = p_{1234} - p_{123} - p_{234} + p_{23} \text{, etc} \quad \ldots\ldots\ldots\ldots \quad \text{(VII)}$$

(d) The factor "s" in formula (II) shall be determined for the final stage of flooding for each compartment and for each group of compartments by formulae (VIII) and (IX).

(i) In general, for any condition of flooding from any initial draught d_i, s_i shall be:

$$\left.\begin{array}{ll} s_i = 2.70\left[\left(\frac{F_1}{B_2} - \frac{\tan\theta}{2}\right)\left(GM_R - MM_S\right)\right]^{\frac{1}{2}} & \text{(in feet)} \\ s_i = 4.9\left[\left(\frac{F_1}{B_2} - \frac{\tan\theta}{2}\right)\left(GM_R - MM_S\right)\right]^{\frac{1}{2}} & \text{(in metres)} \end{array}\right) \quad \ldots\ldots\ldots\ldots \quad \text{(VIII)}$$

but not more than 1.0

Where:

θ = the angle of heel due to unsymmetrical flooding in the final condition after cross-flooding, if any;

GM_R = the highest required intact metacentric height at the relative draught, as determined in Regulation 5(e) or if a higher metacentric height is to be specified in the instructions to the Master, that value may be used;

MM_S = the reduction in the height of the metacentre as a result of flooding, calculated for the ship in the upright position in the final stage of flooding.

(ii) For each compartment and for each group of compartments, "s" is taken as:

$$s = 0.45 s_1 + 0.33 s_2 + 0.22 s_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(IX)}$$

Where:

$s_1 = s_i$ calculated for the ship at initial draught d_1

$s_2 = s_i$ " " " " " " " d_2

$s_3 = s_i$ " " " " " " " d_3

d_1, d_2 and d_3 as defined in Regulation 1(g)(iii).

Values of GM_R for the draughts d_1, d_2 and d_3 are determined from the plot of GM_R versus draught to be furnished to the Master of the ship in accordance with Regulation 8. Values of

MM_S, θ and F_1 for these draughts are determined from plots of damaged condition vertical metacentre, trim, draught and heel versus undamaged draught, determined in accordance with Regulation 5(e).

(iii) Provided a positive contribution to the attained Subdivision Index A is obtained thereby, the flooding of combinations of adjacent compartments in excess of those required for compliance with Regulation 5(b)(i) and (ii) may be included in the calculations. However, s_i shall be taken as zero for any case of flooding which results

(1) during intermediate flooding or prior to equalization in an angle of heel in excess 20 degrees or which immerses any opening through which downflooding might take place.

(2) for the final stage of flooding, except in way of the flooded compartment or com ments, in immersion of the relevant bulkhead deck at side, or heel in excess of 12 degrees. $(GM_R - MM_S)$ less than 2 inches (0.05 metre).

Regulation 7 – Combined Longitudinal and Transverse Subdivision

(a) Regulation 6 is predicated upon the condition that transverse bulkheads ordinarily extend from side to side. However, an Administration may also accept a combination of transverse and longitudinal watertight bulkheads wherein some of the transverse watertight bulkheads extend inboard only to longitudinal watertight bulkheads, provided that:

(i) A horizontal watertight division located not less than $0.1B_1$ above the base line is fitted in the centre space between the longitudinal bulkheads, and the space below the horizontal division is subdivided by watertight bulkheads in line with the watertight transverse bulkheads in the wings or by equivalent means.

(ii) Compliance with the provisions of Regulation 5 is demonstrated.

(iii) The Subdivision Index A, calculated according to paragraphs (b) and (c) of this Regulation is not less than the required Subdivision Index R.

(b) To calculate the contribution of the wing compartments to the attained Subdivision Index A:

(i) "a" is calculated as in Regulation 6(b) using the distances from the aft terminal of L_s to the transverse bulkheads bounding the considered wing compartment or group of compartments.

(ii) "p" is obtained by multiplying the values obtained by application of formulae (IV) of Regulation 6(c) by the reduction factor "r" according to formulae (X), which represents the probability that the inboard spaces will not be flooded.

(1) Where ℓ/L_s is equal to or more than $0.2\ b/B_1$:

$$r = \frac{b}{B_1}\left[2.8 + 0.08/(\ell/L_s + 0.02)\right]$$

if b/B_1 is equal to or less than 0.2, and

$$r = 0.016/(\ell/L_s + 0.02) + b/B_1 + 0.36 \qquad \text{(X)}$$

if b/B_1 is greater than 0.2.

(2) Where ℓ/L_s is less than $0.2\ b/B_1$, r shall be determined by linear interpolation between 1.0 for $\ell/L_s = 0$ and the r-value calculated by formulae (X) for $\ell/L_s = 0.2\ b/B_1$.

In formulae (X) the terms have the following meaning:

ℓ = the distance between the longitudinal limits used for the calculation of "a" and "p" as defined in Regulation 6(b) and (c).

b = the mean transverse distance measured at right angles to the centreline at the subdivision loadline between the shell and a plane through the outermost portion of and parallel to that part of the longitudinal bulkhead which extends between the longitudinal limits used in calculating "a".

(iii) "s" is calculated as in Regulation 6(d), treating the inboard spaces as not floodable, i.e. $\mu = 0$.

(c) If the attained Subdivision Index A obtained by application of the procedures in paragraph (b) of this Regulation is less than the required Subdivision Index R, the additional contribution to the attained Subdivision Index A attributable to flooding of spaces inboard of the longitudinal bulkheads together with the outboard spaces may be included. For the purposes of this contribution:

(i) "a" is calculated as in sub-paragraph (b)(i) of this Regulation except that the distances from the aft terminal of L_s are taken to each transverse bulkhead bounding either a wing or an inboard compartment or group thereof.

(ii) "p" is obtained by multiplying the values obtained by application of formulae (IV) through (VIII) of Regulation 6(c) by (1 – r).

(iii) "s" is calculated as in Regulation 6(d). In so doing, the assumed extent of flooding of both wing and inboard spaces shall be that which would result from an assumed longitudinal extent of damage coincidental with the longitudinal limits used in calculating "a" and "p" and extending in to the ship's centreline.

Regulation 8 – Stability Information

(a) (i) Every passenger ship shall be inclined upon its completion and the elements of its stability determined.

(ii) Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information shall be provided. If necessary the ship shall be re-inclined.

(b) The Master of the ship shall be supplied with such reliable information as is necessary to enable him by rapid and simple means to obtain accurate guidance as to the stability of the ship under varying conditions of service which information shall include:

(i) a curve of minimum operational metacentric height versus draught which assures compliance with the requirements of Regulations 5, 6 and 7, as well as a corresponding curve of the maximum allowable vertical centre of gravity versus draught, or with the tabular equivalents of these curves;

(ii) tables containing draught limits and their corresponding trim limits within which the requirements of Regulations 5, 6 and 7 can be met;

(iii) instructions concerning the operation of cross-flooding arrangements; and

(iv) all other data and aids which might be necessary to maintain the required stability after damage.

(c) There shall be permanently exhibited, for the guidance of the officer in charge of the ship, plans showing clearly for each deck and hold the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding. In addition, booklets containing the aforementioned information shall be made available to the officers of the ship.

(d) All information called for by this Regulation shall be subject to approval by the Administration.

Regulation 9 – **Ballasting**

When ballasting with water is necessary, the water ballast should not in general be carried in tanks intended for oil fuel. In ships in which it is not practicable to avoid putting water in oil fuel tanks, oily-water separator equipment to the satisfaction of the Administration shall be fitted, or other alternative means acceptable to the Administration shall be provided for disposing of the oily-water ballast.

Regulation 10 – Peak and Machinery Space Bulkheads, Shaft Tunnels, etc.

(a) (i) A ship shall have a forepeak or collision bulkhead, which shall be watertight up to the relevant bulkhead deck. This bulkhead shall be fitted not less than $0.05L_s$ and not more than 9.8 feet (or 3.0 metres) + $0.05L_s$ abaft the forward terminal of the deepest subdivision loadline.

(ii) If a ship has a long forward superstructure and the residual freeboard at the forward terminal of L_s after flooding of the foremost compartment is less than the summer freeboard required amidships according to the International Convention on Load Lines, 1966 the collision bulkhead shall be extended weathertight to the deck next above the relevant bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is at least $0.05L_s$ abaft the forward terminal of the deepest subdivision loadline and the part of the relevant bulkhead deck which forms the step is made effectively weathertight.

(b) An afterpeak bulkhead and bulkheads dividing the machinery space from the cargo and passenger spaces forward and aft shall also be fitted and made watertight up to the relevant bulkhead deck. The afterpeak bulkhead may, however, be stepped below the relevant bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

(c) In all cases stern tubes shall be enclosed in watertight spaces of moderate volume. The stern gland shall be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the relevant bulkhead deck will not be submerged.

Regulation 11 – Double Bottoms

(a) A double bottom shall be fitted extending from the forepeak bulkhead to the afterpeak bulkhead as far as this is practicable and compatible with the design and proper working of the ship.

(i) In ships 165 feet (or 50 metres) and under 200 feet (or 61 metres) in length a double bottom shall be fitted at least from the machinery space to the forepeak bulkhead, or as near thereto as practicable.

(ii) In ships 200 feet (or 61 metres) and under 249 feet (or 76 metres) in length a double bottom shall be fitted at least outside the machinery space, and shall extend to the fore and after peak bulkheads, or as near thereto as practicable.

(iii) In ships 249 feet (or 76 metres) in length and upwards a double bottom shall be fitted amidships, and shall extend to the fore and after peak bulkheads, or as near thereto as practicable.

(b) Where a double bottom is required to be fitted its depth shall be to the satisfaction of the Administration and the inner bottom shall be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the line of intersection of the outer edge of the margin plate with the bilge plating is not lower at any part than a horizontal plane passing through the point of intersection with the frame line amidships of a transverse diagonal line inclined at 25 degrees to the base line and cutting it at a point $0.5B_1$ from the middle line.

(c) Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., shall not extend downwards more than necessary. The depth of the well shall in no case be more than the depth less 18 inches (or 457 millimetres) of the double bottom at the centreline, nor shall the well extend below the horizontal plane referred to in paragraph (b) of this Regulation. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel of screw ships. Other wells (e.g. for lubricating oil under main engines) may be permitted by the Administration if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this Regulation.

(d) A double bottom need not be fitted in way of watertight compartments of moderate size used exclusively for the carriage of liquids, provided the safety of the ship, in the event of bottom or side damage, is not, in the opinion of the Administration, thereby impaired.

Regulation 12 – Assigning, Marking and Recording of Subdivision Loadlines

(a) In order that the required degree of subdivision shall be maintained, a loadline corresponding to the approved subdivision draught shall be assigned and marked on the ship's sides. A ship having spaces which are specially adapted for the accommodation of passengers and the carriage of cargo alternatively may, if the owners desire, have one or more additional loadlines assigned and marked to correspond with the subdivision draughts which the Administration may approve for the alternative service conditions.

(b) The subdivision loadlines assigned and marked shall be recorded in the Passenger Ship Safety Certificate, and shall be distinguished by the notation C.1 for the principal passenger condition, and C.2, C.3, etc., for the alternative conditions.

(c) The freeboard corresponding to each of these loadlines shall be measured at the same position and from the same deck line as the freeboards determined in accordance with the International Convention on Load Lines, 1966.

(d) The freeboard corresponding to each approved subdivision loadline and the conditions of service for which it is approved, shall be clearly indicated on the Passenger Ship Safety Certificate.

(e) In no case shall any subdivision loadline mark be placed above the deepest loadline in salt water as determined by the strength of the ship and/or the International Convention on Load Lines, 1966.

(f) Whatever may be the position of the subdivision loadline marks, a ship shall in no case be loaded so as to submerge the loadline mark appropriate to the season and locality as determined in accordance with the International Convention on Load Lines, 1966.

(g) A ship shall in no case be so loaded that when she is in salt water the subdivision loadline mark appropriate to the particular voyage and condition of service is submerged.

Regulation 13 – Construction and Initial Testing of Watertight Bulkheads, etc.

(a) Each watertight subdivision bulkhead whether transverse or longitudinal shall be constructed in such a manner that it shall be capable of supporting, with a proper margin of resistance, the pressure due to the maximum head of water which it might have to sustain in the event of damage to the ship, but at least the pressure due to a head of water up to the immersion limit line. The construction of these bulkheads shall be to the satisfaction of the Administration.

(b) (i) Steps and recesses in bulkheads shall be watertight and as strong as the bulkhead at the place where each occurs.

(ii) Where frames or beams pass through a watertight deck or bulkhead such deck or bulkhead shall be made structurally watertight without the use of wood or cement.

(c) Testing main compartments by filling them with water is not compulsory. When testing by filling with water is not carried out, a hose test is compulsory; this test shall be carried out in the most advanced stage of the fitting out of the ship. In any case, a thorough inspection of the watertight bulkheads shall be carried out.

(d) The forepeak, double bottoms (including duct keels) and inner skins shall be tested with water to a head corresponding to the requirements of paragraph (a) of this Regulation.

(e) Tanks which are intended to hold liquids, and which form part of the subdivision of the ship, shall be tested for tightness with water to a head up to the deepest subdivision loadline or to a head corresponding to two-thirds of the depth from the top of the keel to the immersion limit line in way of the tanks, whichever is the greater; provided that in no case shall the test head be less than 3 feet (or 0.92 metre) above the top of the tank.

(f) The tests referred to in paragraphs (d) and (e) of this Regulation are for the purpose of ensuring that the subdivision structural arrangements are watertight and are not to be regarded as a test of the fitness of any compartment for the storage of oil fuel or for other special purposes for which a test of a superior character may be required depending on the height to which the liquid has access in the tank or its connections.

Regulation 14 – Openings in Watertight Bulkheads

(a) The number of openings in watertight bulkheads shall be reduced to the minimum compatible with the design and proper working of the ship; satisfactory means shall be provided for closing these openings.

(b) (i) Where pipes, scuppers, electric cables, etc. are carried through watertight subdivision bulkheads, arrangements shall be made to ensure the integrity of the watertightness of the bulkheads.

(ii) Valves and cocks not forming part of a piping system shall not be permitted in watertight subdivision bulkheads.

(iii) Lead or other heat sensitive materials shall not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

(c) (i) No doors, manholes, or access openings are permitted:

(1) in the collision bulkhead below the relevant bulkhead deck;

(2) in watertight transverse bulkheads dividing a cargo space from an adjoining cargo space, except as provided in paragraph (k) of this Regulation.

(ii) Except as provided in sub-paragraph (iii) of this paragraph, the collision bulkhead may be pierced below the relevant bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screwdown valve capable of being operated from above the immersion limit line, the valve chest being secured inside the forepeak to the collision bulkhead.

(iii) If the forepeak is divided to hold two different kinds of liquids the Administration may allow the collision bulkhead to be pierced below the relevant bulkhead deck by two pipes, each of which is fitted as required by sub-paragraph (ii) of this paragraph, provided the Administration is satisfied that there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the ship is maintained.

(d) Within spaces containing the main and auxiliary propelling machinery including boilers serving the needs of propulsion not more than one door apart from the doors to shaft tunnels may be fitted in each main transverse bulkhead. Where two or more shafts are fitted the tunnels shall be connected by an intercommunicating passage. There shall be only one door between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts. All these doors shall be of the sliding type and shall be

located so as to have their sills as high as practicable. The hand gear for operating these doors shall be situated above the immersion limit line and outside the spaces containing the machinery if this is consistent with a satisfactory arrangement of the necessary gearing.

(e) (i) Watertight doors shall be sliding doors or hinged doors or doors of an equivalent type. Plate doors secured only by bolts and doors required to be closed by dropping or by the action of a dropping weight are not permitted.

(ii) Sliding doors may be either:

hand operated only, or power operated as well as hand operated.

(iii) Authorized watertight doors may therefore be divided into three Classes:

Class 1 – hinged doors;
Class 2 – hand operated sliding doors;
Class 3 – sliding doors which are power operated as well as hand operated.

(iv) The means of operation of any watertight door whether power operated or not shall be capable of closing the door with the ship listed to 15 degrees either way.

(v) In all classes of watertight doors indicators shall be fitted which show, at all operating stations from which the doors are not visible, whether the doors are open or closed. If any of the watertight doors, of whatever Class, is not fitted so as to enable it to be closed from a central control station, it shall be provided with a mechanical, electrical, telephonic, or any other suitable direct means of communication, enabling the officer of the watch promptly to contact the person who is responsible for closing the door in question, under previous orders.

(f) Hinged doors (Class 1) shall be fitted with quick action closing devices, such as catches, workable from each side of the bulkhead.

(g) Hand operated sliding doors (Class 2) may have a horizontal or vertical motion. It shall be possible to operate the mechanism at the door itself from either side, and in addition, from an accessible position above the immersion limit line, with an all round crank motion, or some other movement providing the same guarantee of safety and of an approved type. Departures from the requirement of operation on both sides may be allowed, if this requirement is impossible owing to the layout of the spaces. When operating a hand gear, the time necessary for the complete closure of the door with the ship upright shall not exceed 90 seconds.

(h) (i) Power operated sliding doors (Class 3) may have a vertical or horizontal motion. If a door is required to be power operated from a central control, the gearing shall be so arranged that the door can be operated by power also at the door itself from both sides. The arrangement shall be such that the door will close automatically if opened by local control after being closed from the central control, and also such that any door can be kept closed by local systems which will prevent the door from being opened from the upper control. Local control handles in connection with the power gear shall be provided each side of the bulkhead and shall be so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the closing mechanism in operation accidentally. Power operated sliding doors shall be provided with hand gear workable at the door itself on either side and from an accessible position above the immersion limit line, with an all round crank motion or some other movement providing the same guarantee of safety and of an approved type. Provision shall be made to give warnings by sound signal that the door has begun to close and will continue to move until it is completely closed. The door shall take a sufficient time to close to ensure safety.

(ii) There shall be at least two independent power sources capable of opening and closing all the doors under control, each of them capable of operating all the doors simultaneously. The two power sources shall be controlled from the central station on the bridge provided with all the necessary indicators for checking that each of the two power sources is capable of giving the required service satisfactorily.

(iii) In the case of hydraulic operation, each power source shall consist of a pump capable of closing all doors in not more than 60 seconds. In addition, there shall be for the whole installation hydraulic accumulators of sufficient capacity to operate all the doors at least three times, i.e. closed–open–closed. The fluid used shall be one which does not freeze at any of the temperatures liable to be encountered by the ship during its service.

(i) (i) Hinged watertight doors (Class 1) in passenger, crew and working spaces are only permitted above a deck the underside of which, at its lowest point at side, is at least 7 feet (or 2.13 metres) above the deepest subdivision loadline.

(ii) Watertight doors, the sills of which are above the deepest subdivision loadline and below the line specified in sub-paragraph (i) of this paragraph shall be sliding doors and may be hand operated (Class 2), except in ships where N is 1200 or more in which all such doors shall be power operated. When trunkways in connection with refrigerated cargo and ventilation or forced draught ducts are carried through more than one main watertight subdivision bulkhead, the doors at such openings shall be operated by power.

(j) Watertight doors which may sometimes be opened at sea, and the sills of which are below the deepest subdivision loadline, shall be sliding doors. The following rules shall apply:

(1) when the number of such doors (excluding doors at entrances to shaft tunnels) exceeds five all of these doors and those at the entrance to shaft tunnels or ventilation or forced draught ducts, shall be power operated (Class 3) and shall be capable of being simultaneously closed from a central station situated on the bridge;

(2) when the number of such doors (excluding doors at entrances to shaft tunnels) is greater than one, but does not exceed five,

(a) where the ship has no passenger spaces below the immersion limit line, all the above-mentioned doors may be hand operated (Class 2);

(b) where the ship has passenger spaces below the immersion limit line all the above-mentioned doors shall be power operated (Class 3) and shall be capable of being simultaneously closed from a central station situated on the bridge;

(3) in any ship where there are only two such watertight doors and they are into or within the space containing machinery, the Administration may allow these two doors to be hand operated only (Class 2).

(k) (i) If the Administration is satisfied that such doors are essential, watertight doors of satisfactory construction may be fitted in watertight bulkheads dividing cargo between deck spaces. Such doors may be hinged, rolling or sliding doors but shall not be remotely controlled. They shall be fitted at the highest level and as far from the shell plating as practicable, but in no case shall the outboard vertical edges be situated at a distance from the shell plating which is less than $0.2B_1$, such distance being measured at right angles to the centreline of the ship at the level of the deepest subdivision loadline.

(ii) Such doors shall be closed before the voyage commences and shall be kept closed during navigation, and the time of opening such doors in port and of closing them before the ship leaves port shall be entered in the log book. Should any of the doors be accessible during the voyage, they shall be fitted with a device which prevents unauthorized opening. When it is proposed to fit such doors, the number and arrangements shall receive the special consideration of the Administration.

(l) Portable plates on bulkheads shall not be permitted except in machinery spaces. Such plates shall always be in place before the ship leaves port, and shall not be removed during navigation except in case of urgent necessity. The necessary precautions shall be taken in replacing them to ensure that the joints shall be watertight.

(m) All watertight doors shall be kept closed during navigation except when necessarily opened for the working of the ship, and shall always be ready to be immediately closed.

(n) (i) Where trunkways or tunnels for piping, or for any other purpose are carried through main transverse watertight bulkheads, they shall be watertight and in accordance with the requirements of Regulation 17. The access to at least one end of each such tunnel or trunkway, if used as a passage at sea, shall be through a trunk extending watertight to a height sufficient to permit access above the relevant bulkhead deck. The access to the other end of the trunkway or tunnel may be through a watertight door of the type required by its location in the ship. Such trunkways or tunnels shall not extend through the first subdivision bulkhead abaft the collision bulkhead.

(ii) Where it is proposed to fit tunnels or trunkways for forced draught, piercing main transverse watertight bulkheads, these shall receive the special consideration of the Administration.

Regulation 15 – Openings in the Shell Plating below the Immersion Limit Line

(a) The number of openings in the shell plating shall be reduced to the minimum compatible with the design and proper working of the ship.

(b) The arrangement and efficiency of the means for closing any opening in the shell plating shall be consistent with its intended purpose and the position in which it is fitted and generally to the satisfaction of the Administration.

(c) (i) If in a between deck the sills of any sidescuttles are below a line drawn parallel to the immersion limit line at side and having its lowest point $0.025B_1$ above the deepest subdivision loadline, all sidescuttles in that between deck shall be of the non-opening type.

(ii) All sidescuttles, the sills of which are below the immersion limit line, other than those required to be of a non-opening type by sub-paragraph (i) of this paragraph, shall be of such construction as will effectively prevent any person opening them without the consent of the Master of the ship

(iii) (1) Where in a between deck the sills of any of the sidescuttles referred to in sub-paragraph (ii) of this paragraph are below a line drawn parallel to the immersion limit line, and having its lowest point 4½ feet (or 1.37 metres) + $0.025B_1$ above the water when the ship departs from any port, all the sidescuttles in that between deck shall be closed watertight and locked before the ship leaves port, and they shall not be opened before the ship arrives at the next port. In the application of this sub-paragraph the appropriate allowance for fresh water may be made when applicable.

(2) The time of opening such sidescuttles in port and of closing and locking them before the ship leaves port shall be entered in such log book as may be prescribed by the Administration.

(d) Efficient hinged inside deadlights arranged so that they can be easily and effectively closed and secured watertight shall be fitted to all sidescuttles except that abaft $0.125L_s$ from the forward terminal of L_s and above a line drawn parallel to the immersion limit line and having its lowest point at a height of 12 feet (or 3.66 metres) + $0.025B_1$ above the deepest subdivision loadline the deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines, 1966 to be permanently attached in their proper positions. Such portable deadlights shall be stowed adjacent to the sidescuttles they serve.

(e) Sidescuttles and their deadlights, which will not be accessible during navigation, shall be closed and secured before the ship leaves port.

(f) (i) No sidescuttles shall be fitted in any spaces which are appropriated exclusively to the carriage of cargo.

(ii) Sidescuttles may, however, be fitted in spaces appropriated *alternatively to the carriage* of cargo or passengers, but they shall be of such construction as will effectively prevent any person opening them or their deadlights without the consent of the Master of the ship.

(iii) If cargo is carried in such spaces, the sidescuttles and their deadlights shall be closed watertight and locked before the cargo is shipped and such closing and locking shall be recorded in such log book as may be prescribed by the Administration.

(g) Automatic ventilating sidescuttles shall not be fitted in the shell plating below the immersion limit line without the special sanction of the Administration.

(h) The number of scuppers, sanitary discharges and other similar openings in the shell plating shall be reduced to the minimum either by making each discharge serve for as many as possible of the sanitary and other pipes, or in any other satisfactory manner.

(i) (i) All inlets and discharges in the shell plating shall be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship. Lead or other heat sensitive materials shall not be used for pipes fitted outboard of shell valves in inlets or discharges, or any other application where the deterioration of such pipes in the event of fire would give rise to danger of flooding.

(ii) (1) Except as provided in sub-paragraph (iii) of this paragraph, each separate discharge led through the shell plating from spaces below the immersion limit line shall be provided either with one automatic non-return valve fitted with a positive means of closing it from above the immersion limit line or, alternatively, with two automatic non-return valves without such means, the upper of which is so situated above the deepest subdivision loadline as to be always accessible for examination under service conditions, and is of a type which is normally closed.

(2) Where a valve with positive means of closing is fitted, the operating position above the immersion limit line shall always be readily accessible, and means shall be provided for indicating whether the valve is open or closed.

(iii) Main and auxiliary sea inlets and discharges in connection with machinery shall be fitted with readily accessible cocks or valves between the pipes and shell plating or between the pipes and fabricated boxes attached to the shell plating.

(j) (i) Gangway, cargo and bunkering station ports fitted below the immersion limit line shall be of sufficient strength. They shall be effectively closed and secured watertight before the ship leaves port, and shall be kept closed during navigation.

(ii) Such ports shall be in no case fitted so as to have their lowest point below the deepest subdivision loadline.

(k) (i) The inboard opening of each rubbish-shoot, etc., shall be fitted with an efficient cover.

(ii) If the inboard opening is situated below the immersion limit line the cover shall be watertight, and in addition an automatic non-return valve shall be fitted in the shoot in an easily accessible position above the deepest subdivision loadline. When the shoot is not in use both the cover and the valve shall be kept closed and secured.

Regulation 16 – Construction and Initial Tests of Watertight Doors, Sidescuttles, etc.

(a) (i) The design, materials and construction of all watertight doors, sidescuttles, gangway, cargo and other ports, valves, pipes, and rubbish-shoots referred to in these Regulations shall be to the satisfaction of the Administration.

(ii) The frames of vertical watertight doors shall have no groove at the bottom in which dirt might lodge and prevent the door closing properly.

(iii) All cocks and valves for sea inlets and discharges below the immersion limit line and all fittings outboard of such cocks and valves shall be made of steel, bronze or other approved ductile material. Ordinary cast iron or similar materials shall not be used.

(b) Each watertight door shall be tested by water pressure to a head up to the immersion limit line. The test shall be made before the ship is put in service, either before or after the door is fitted.

Regulation 17 -- Construction and Initial Tests of Watertight Decks, Trunks, etc.

(a) Watertight decks, trunks, tunnels, duct keels and ventilators shall be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, shall be to the satisfaction of the Administration. Watertight ventilators and trunks shall be carried at least up to the immersion limit line.

(b) After completion, a hose or flooding test shall be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.

Regulation 18 – Watertight Integrity above the relevant Bulkhead Deck

(a) The Administration may require that all reasonable and practicable measures shall be taken to limit the entry and spread of water above the relevant bulkhead deck. Such measures may include partial bulkheads or webs. When partial watertight bulkheads and webs are fitted on the relevant bulkhead deck, above or in the immediate vicinity of main subdivision bulkheads, they shall have watertight shell and relevant bulkhead deck connections so as to restrict the flow of water along the deck when the ship is in a heeled damaged condition. Where the partial watertight bulkhead does not line up with the bulkhead below, the relevant bulkhead deck between shall be made effectively watertight.

(b) The deck at the immersion limit line or a deck above it shall be weathertight in the sense that in ordinary sea conditions water will not penetrate in a downward direction. All openings in the exposed weather deck shall have coamings of ample height and strength and shall be provided with efficient means for expeditiously closing them weathertight. Freeing ports, open rails and/or scuppers shall be fitted as necessary for rapidly clearing the weather deck of water under all weather conditions.

(c) Sidescuttles, gangway, cargo and other ports and other means for closing openings in the shell plating above the immersion limit line shall be of efficient design and construction and of sufficient strength having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision loadline.

(d) Efficient inside deadlights, arranged so that they can be easily and effectively closed and secured watertight, shall be provided for all sidescuttles to spaces below the first deck above the immersion limit line.

Regulation 19 – Bilge Pumping Arrangements

(a) Ships shall be provided with an efficient bilge pumping plant capable of pumping from and draining any watertight compartment which is neither a permanent oil compartment nor a permanent water compartment under all practicable conditions after a casualty whether the ship is upright or listed. For this purpose wing

suctions will generally be necessary except in narrow compartments at the ends of the ship, where one suction may be sufficient. In compartments of unusual form, additional suctions may be required. Arrangements shall be made whereby water in the compartment may find its way to the suction pipes. Where in relation to particular compartments the Administration is satisfied that the provision of drainage may be undesirable, it may allow such provision to be dispensed with if calculations made in accordance with the conditions laid down in Regulation 5 and assumed for the purposes of Regulations 6 and 7 show that the safety of the ship will not be impaired. Efficient means shall be provided for draining water from insulated holds.

(b) (i) Ships shall have at least three power pumps connected to the bilge main, one of which may be attached to the propelling unit. Where R is more than 0.50, one additional independent power pump shall be provided.

(ii) The requirements are summarized in the following table:

Required Subdivision Index R	Less than 0.50	and over 0.50
Main engine pump (may be replaced by one independent pump)	1	1
Independent pumps	2	3

(iii) Sanitary, ballast and general service pumps may be accepted as independent power bilge pumps if fitted with the necessary connections to the bilge pumping system.

(c) Where practicable, the power bilge pumps shall be placed in separate watertight compartments so arranged or situated that these compartments will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the pumps available for bilge service shall be distributed throughout these compartments as far as is possible.

(d) On ships 330 feet (or 100 metres) or more in length or having R more than 0.50, the arrangements shall be such that at least one power pump shall be available for use in all ordinary circumstances in which a ship may be flooded at sea. This requirement will be satisfied if:

(i) one of the required pumps is an emergency pump of a reliable submersible type having a source of power situated above the relevant bulkhead deck; or

(ii) the pumps and their sources of power are so disposed throughout the length of the ship that under any condition of flooding which the ship is required to withstand, at least one pump in an undamaged compartment will be available.

(e) With the exception of additional pumps which may be provided for peak compartments only, each required bilge pump shall be arranged to draw water from any space required to be drained by paragraph (a) of this Regulation.

(f) Each power bilge pump shall be capable of giving a speed of water through the required main bilge pipe of not less than 400 feet (or 122 metres) per minute. Independent power bilge pumps situated in machinery spaces shall have direct suctions from these spaces, except that not more than two such suctions shall be required in any one space. Where two or more such suctions are provided there shall be at least one on the port side and one on the starboard side. The Administration may require independent power bilge pumps situated in other spaces to have separate direct suctions. Direct suctions shall be suitably arranged and those in a machinery space shall be of a diameter not less than that required for the bilge main.

(g) (i) In addition to the direct bilge suction or suctions required by paragraph (f) of this Regulation there shall be in the machinery space a direct suction from the main circulating pump leading to the drainage level of the machinery space and fitted with a non-return valve. The diameter of this direct suction pipe shall be at least two-thirds of the diameter of the pump inlet in the case of steamships, and of the same diameter as the pump inlet in the case of motorships.

(ii) Where in the opinion of the Administration the main circulating pump is not suitable for this purpose, a direct emergency bilge suction shall be led from the largest available independent power driven pump to the drainage level of the machinery space; the suction shall be of the same diameter as the main inlet of the pump used. The capacity of the pump so connected shall exceed that of a required bilge pump by an amount satisfactory to the Administration.

(iii) The spindles of the sea inlet and direct suction valves shall extend well above the engine room platform.

(h) (i) All pipes from the pumps which are required for draining cargo or machinery spaces shall be entirely distinct from pipes which may be used for filling or emptying spaces where water or oil is carried.

(ii) All bilge pipes used in or under fuel storage tanks or in boiler or machinery spaces, including spaces in which oil-settling tanks or oil fuel pumping units are situated, shall be of steel or other approved material.

(i) The diameter of the bilge main shall be calculated according to the following formulae provided that the actual internal diameter of the bilge main may be of the nearest standard size acceptable to the Administration

$$d \text{ (in inches)} = \sqrt{\frac{L_s(B_1 + D_s)}{2{,}500}} + 1$$

or

$$d \text{ (in millimetres)} = 1.68 \sqrt{L_s(B_1 + D_s)} + 25$$

where d = internal diameter of the bilge main (in inches or in millimetres respectively)

L_s and B_1 in feet or metres respectively

D_s = moulded depth of ship to immersion limit line at midlength (in feet or metres respectively).

The diameter of the bilge branch pipes shall be determined by rules to be made by the Administration.

(j) The arrangement of the bilge and ballast pumping system shall be such as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another. Special provision shall be made to prevent any deep tank having bilge and ballast connections being inadvertently run up from the sea when containing cargo, or pumped out through a bilge pipe when containing water ballast.

(k) Provision shall be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $0.2B_1$ (measured at right angles to the centreline at the level of the deepest subdivision loadline), or in a duct keel, a non-return valve shall be fitted to the pipe in the compartment containing the open end.

(l) All the distribution boxes, cocks and valves in connection with the bilge pumping arrangements shall be in positions which are accessible at all times under ordinary circumstances. They shall be so arranged that in the event of flooding, one of the bilge pumps may be operative on any compartment; in addition, damage to a pump or its pipe connecting to the bilge main outboard of a line drawn at $0.2B_1$, shall not put the bilge system out of action. If there is only one system of pipes common to all the pumps, the necessary cocks or valves for controlling the bilge suctions must be capable of being operated from above the immersion limit line. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it shall be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in that case only the cocks and valves necessary for the operation of the emergency system need be capable of being operated from above the immersion limit line.

(m) All cocks and valves mentioned in paragraph (l) of this Regulation which can be operated from above the immersion limit line shall have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

Regulation 20 – Marking, Periodical Operation and Inspection of Watertight Doors, etc.

(a) Drills for the operating of watertight doors, sidescuttles, valves and closing mechanisms of scuppers, and rubbish-shoots shall take place weekly. In ships in which the voyage exceeds one week in duration a complete drill shall be held before leaving port, and others thereafter at least once a week during the voyage. In all ships all watertight power doors and hinged doors, in main transverse bulkheads, in use at sea, shall be operated daily.

(b) (i) The watertight doors and all mechanisms and indicators connected therewith, all valves the closing of which is necessary to make a compartment watertight, and all valves the operation of which is necessary for damage control cross connections, shall be periodically inspected at sea at least once a week.

(ii) Such valves, doors and mechanisms shall be suitably marked to ensure that they may be properly used to provide maximum safety.

Regulation 21 – Entries in Log

(a) Hinged doors, portable plates, sidescuttles, gangway, cargo and other ports and other openings, which are required by these Regulations to be kept closed during navigation, shall be closed before the ship leaves port. The time of closing and the time of opening (if permissible under these Regulations) shall be recorded in such log book as may be prescribed by the Administration.

(b) A record of all drills and inspections required by Regulation 20 shall be entered in the log book with an explicit record of any defects which may be disclosed.

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IMCO

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REGULATIONS ON SUBDIVISION AND DAMAGE STABILITY OF PASSENGER SHIPS AS EQUIVALENT TO PART B OF CHAPTER II OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960 (Resolution A.265(VIII))

<u>Explanatory notes to the Regulations</u>

The Assembly at its eighth session when adopting the Regulations on Subdivision and Stability of Passenger Ships as an equivalent to Part B of Chapter II of the International Convention for the Safety of Life at Sea, 1960 (Resolution A.265(VIII)), considered explanatory notes to those Regulations, which were prepared by the Sub-Committee on Subdivision and Stability.

The Assembly agreed that this supporting document was of great value in ensuring the uniform application of the Regulations and recommended its circulation to Member Governments and Contracting Governments to the 1960 Safety Convention for information.

The text of the explanatory notes (Annex II of STAB XV/11) is attached hereto.

ANNEX II

EXPLANATORY NOTES TO THE REGULATIONS ON SUBDIVISION AND DAMAGE STABILITY OF PASSENGER SHIPS AS EQUIVALENT TO PART B OF CHAPTER II OF THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

The following notes are applicable to new Regulations 1-21 which, in accordance with Resolution A.265(VIII), may be taken as equivalent to and a total alternative to the corresponding provisions of Part B of Chapter II of the International Convention for the Safety of Life at Sea, 1960.

The new Regulations have been prepared in response to Recommendation 6 of the above Convention.

These notes consist of the following four parts:

I. General Principles;

II. Guidance Notes for Application of Regulations;

III. Guidance for Assembling Input Data and Structuring Output Data;

IV. Basis for the Calculation of Subdivision Index A.

Part I contains a brief history of the development of the new Regulations together with an explanation concerning the need for the revision of the present requirements. Additionally, explanation is given in respect of the basic philosophy as well as the general principles and practical advantages of the new requirements.

Parts II and III are intended for users of the new Regulations. Part II gives detailed explanation on each regulation and Part III describes a recommended form for input and output data.

Part IV provides information for those who wish to study the theoretical basis for the new Regulations. In this part a summary of statistics upon which these Regulations are based is also given.

PART I - GENERAL PRINCIPLES

In this part of the explanatory note a general outline of the new Subdivision Regulations is given together with a brief history of their development. More detailed information is presented in subsequent parts.

The regulations dealing with the subdivision of passenger ships in the 1960 Safety Convention were derived from studies carried out prior to and after the first International Safety Conference of 1913-1914. These studies took place mainly during the period 1912-1924 and were influenced by then existing ships. The 1960 Safety Convention regulations therefore, in the main, do not take into account evolution in ship design and advances in knowledge over about the past 50 years.

Ship design has changed considerably since then and with the passage of time the present method has become less meaningful as regards safety. Additionally, from a more comprehensive study, certain flaws in the method have been disclosed.

Among the defects of the existing subdivision regulations of the 1960 Safety Convention which were considered as a reason for their revision are:

- The formulae for the Criterion of Service have become obsolete because the relationship between the volumes of different spaces within the ship's hull (which was introduced in these formulae in a hidden way) has changed since these formulae were produced. Improvements in machinery design have permitted higher power within less space. There has been a demand for more spacious passenger accommodations causing them to be located to a greater degree above the bulkhead deck. In consequence, the safety standard applied to a ship whose primary function is the carriage of passengers has depreciated.

- The regulations in the 1960 Safety Convention do not take into account the fact that for any given bulkhead arrangement quite different extents of flooding can arise as a result of varying damage length which is a random quantity.

- The method employed in the 1960 Safety Convention does not take full account of the effects of ship proportions, of operation at draughts less than the load draught, of variations in permeability, or of stability flooded on the degree of safety.

These and some other deficiencies of the regulations in the 1960 Safety Convention lead to an incorrect estimate of the ship's safety. In particular, the method used in the 1960 Safety Convention calls two ships equally safe if they have the same value of subdivision factor though these ships may have quite different actual capabilities to withstand damage.

At the International Conference on Safety of Life at Sea, 1960 several countries, including Federal Republic of Germany, Italy, Japan, the United States and the Soviet Union, submitted proposals for amendments to Chapter II of the 1948 Safety Convention in respect of subdivision and damage stability regulations. Although these proposals were not accepted by the Conference, it was agreed that improvement in these regulations was desirable. In Recommendation 6, the Conference noted that IMCO should, at the earliest practicable date, carry out investigations directed towards improvement.

A principal task of the IMCO Sub-Committee on Subdivision and Stability, established in 1962, has been to carry out this work.

In 1967, after many preliminary studies, the Sub-Committee established the Ad Hoc Group for the preparation of new Regulations.

Since establishment of the Sub-Committee, and including the Ad Hoc Group, more than 25 international meetings have been held and more than 150 relevant papers have been considered.

The background theoretical and experimental work has been extensive and has involved a high degree of cooperation among countries both in undertaking this work and in the discussions within the Sub-Committee. It may be also said that the new Regulations reflect a considerable degree of contribution from all Members of the Sub-Committee.

In preparing the new Subdivision Regulations the following main premises were taken as a basis:

- The level of safety provided by the new Regulations should, in general, be similar to that given by the 1960 Safety Convention.

- The degree of safety should increase with the ship length and the total number of persons which the ship is certified to carry.

- As a criterion of the degree of safety an index of subdivision which is a measure of the ship's ability to survive after damage should be used. This index should reflect the effect of bulkhead spacing, stability, and other features relevant to this ability.

- Since a purely probabilistic approach to evaluation of safety would lead in some cases, to design of ships with unacceptable vulnerability in some part of their length, the regulations should include specific minimum standards for compartmentation and damage stability leading to approximately the same degree of safety in these respects, as is provided by the Regulations of the 1960 Safety Convention.

The most important and principal distinction of the new Regulations is the use of the probabilistic approach.

As it is well known, many factors actually affecting the final consequences of ship hull damage are random and their influence is different for ships with different characteristics. For example, it is obvious that in ships of similar size carrying different amounts of cargo, quite similar damages may lead to different results because of differences in the range of permeability and draught during service.

Due to this fact, the effect of damage to a ship with given watertight subdivision depends on the following circumstances:

- which particular compartment or group of adjacent compartments is flooded;

- the draught and intact stability at the time of damage;
- the permeability of affected spaces at the time of damage;
- the sea state at the moment of damage;
- other factors such as possible heeling moments due to unsymmetrical weights.

Some of these circumstances are interdependent and the relationship between them and their effects may vary in different cases.

For these reasons and because of mathematical complexity as well as insufficient data, it is not practicable to make an exact or direct assessment of their effect on the probability that a particular ship will survive a damage if it occurs. However, accepting some approximations or qualitative judgments, a logical treatment may be achieved by using the probability approach as the basis of a comparative method for the assessment and regulation of ship safety.

The probability of ship's survival includes the following probabilities:

- the probability of flooding each single compartment and each possible group of two or more adjacent compartments;
- the probability that the residual buoyancy after flooding of a compartment (or a group of two or more adjacent compartments) under consideration will be sufficient to provide for survival;
- the probability that the stability after flooding a compartment (or a group of two or more adjacent compartments) will be sufficient to prevent capsizing or dangerous heeling due to loss of stability or to heeling moment.

It may be demonstrated by means of the probability theory that the probability of ship survival should be calculated as a sum of probabilities of her survival after flooding each single compartment, each group of two, three etc. adjacent compartments multiplied, respectively, by the probabilities of such damages as lead to the flooding of the corresponding compartment or group of compartments.

The principles of evaluation of the probability of flooding of any given compartment or group of adjacent compartments are shown in Fig.1.1.

Similarly principles of evaulation of the probability of survival after flooding of any given compartment or group of adjacent compartments are shown in Fig. 1.2.

Data analyzed and utilized in preparing the new Regulations include:

- Collision casualty reports giving damage dimensions and location in ship, sea state and other relevant information;
- Voyage reports containing information pertaining to operating draughts and permeabilities (as well as stability);
- Model tests of two damaged ships in waves as well as supplementary tests of simplified models of varying beam to determine the effect of beam-depth ratio.

While the resulting information presently available is considered insufficient to permit a precise determination of ship survival probability, the new regulations lead to a comparative evaluation of ship safety based on probability principles and specifically provide for:

- An objective evaluation of the effect of individual specific ship features on the safety of the ship. In this connexion, the new Regulations, without loss in safety, permit greater latitude in bulkhead arrangement than do the Regulations of the 1960 Safety Convention.
- Possible future improvement in the Regulations, without need for change in their structure, as additional relevant statistical and other information may become available.

Figure 1.1 - Schematic Diagram showing Principles of Calculations of the Probability of Flooding any given part of a Ship's Hull

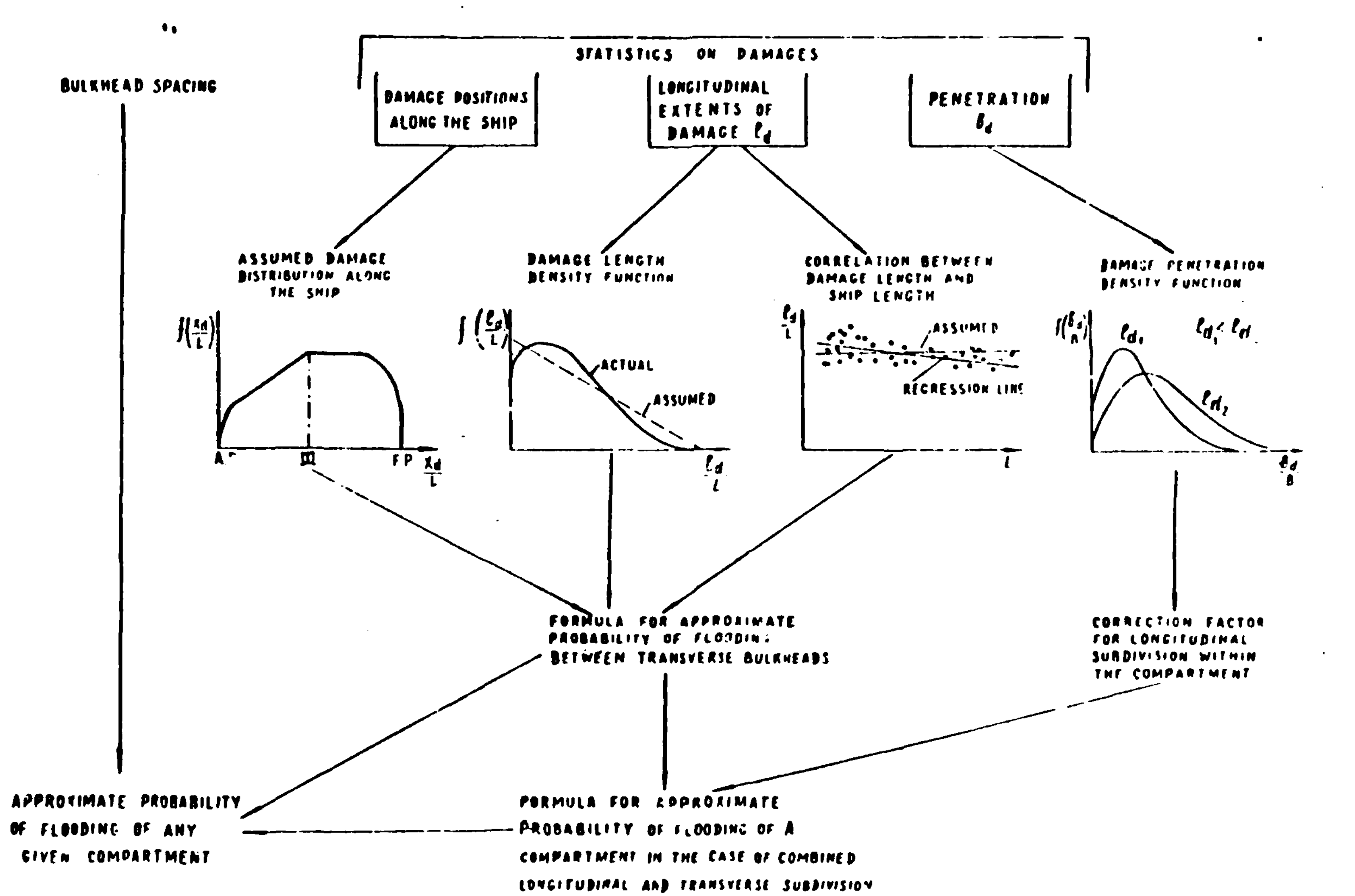
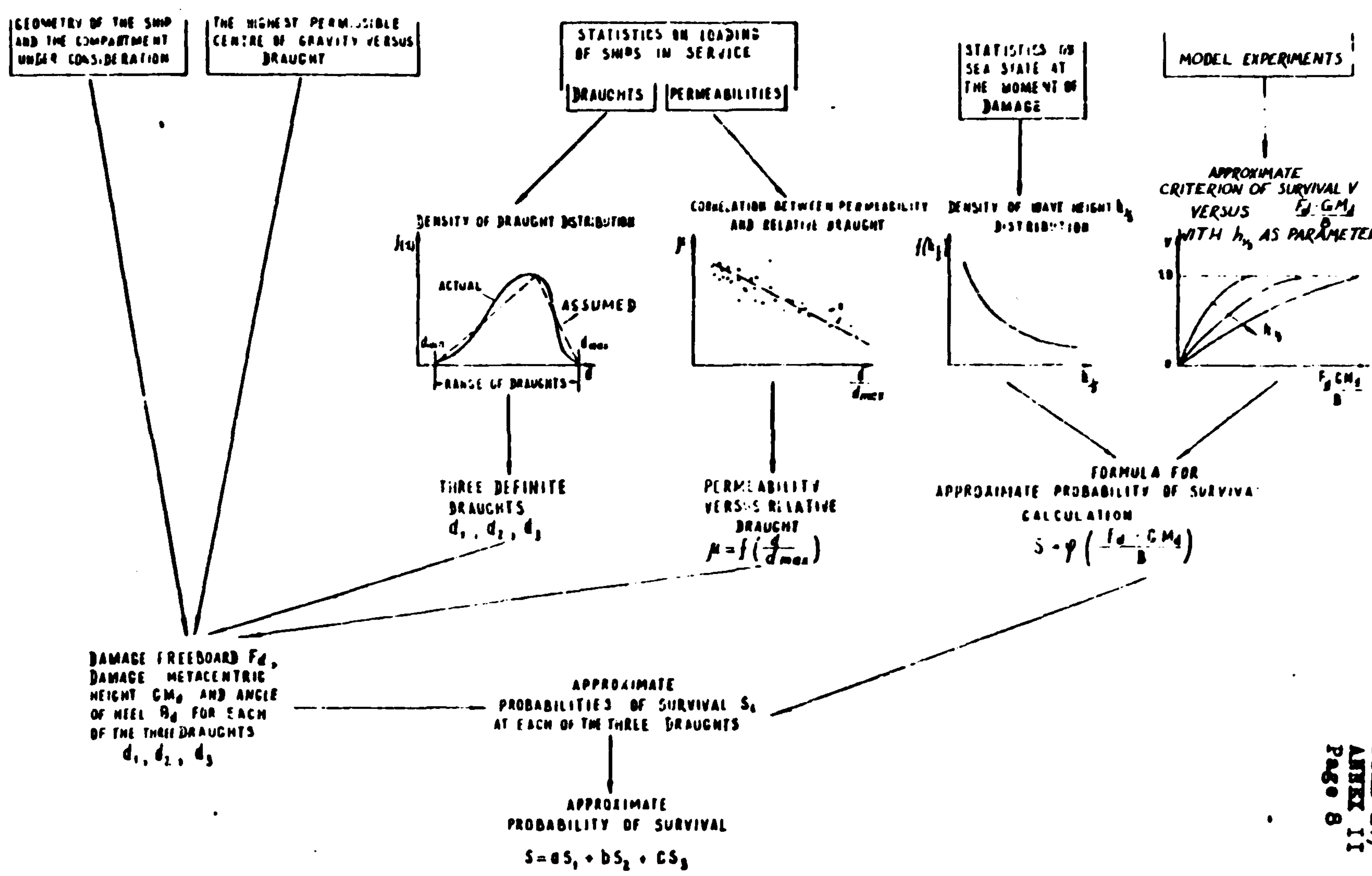


Figure 1.2 - Schematic Diagram showing Principles of Calculation of the Probability of Survival of Flooding of any given part of a Ship's Hull



PART II - GUIDANCE NOTES FOR APPLICATION OF REGULATIONS

In these notes, reference is made to the numbers of the new Regulations. However, where any part of a Regulation is considered sufficiently like its counterpart in Chapter II of the 1960 Safety Convention, or is otherwise fully self-evident, no mention is made.

Regulation 1 - Definitions

Paragraph 1(b). In effect "the subdivision length" (L_s) is the moulded overall length of the buoyant part of the intact ship. In contrast to the length as defined in Regulation 2(b) of Chapter II of the 1960 Safety Convention, it is unaffected by changes in the subdivision draught.

Paragraphs 1(b), (e) and (f) are illustrated by Figure 2.1.

Sub-paragraph 1(g)(ii). The "lightest service draught" (d_o) is normally the anticipated draught with no cargo but with the ship in service condition and with sufficient tankage and ballast to provide the minimum operational metacentric height at that draught prescribed in accordance with Regulation 8(b)(i). However, in the case of ships which may never be operated without at least some cargo aboard, the anticipated minimum cargo should be included.

Sub-paragraph 1(g)(iii). The use of these intermediate draughts is explained under discussion of Regulation 6(d)(ii).

Paragraph 1(h) is illustrated by Figure 2.2.

Regulation 2 - Subdivision Index

This Regulation requires that safety shall increase as L and N are increased, but that the rate of increase of safety shall, for practical reasons, diminish towards the higher end of the scale.

It may be noted that officers and crew are included in the evaluation of N, not only for humanitarian reasons but also because it was found that such inclusion evidently resulted in a better evaluation of the ship's service. That is to say, luxury and cruise ships, devoted virtually exclusively to passengers, tend to have larger crews than ships of about the same size and passenger numbers, but which depend upon cargo revenue for part of their income.

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Figure 2.1 - Illustration of "subdivision length", "relevant bulkhead deck" and "immersion limit line". Regulation 1 (b), (e) and (f)

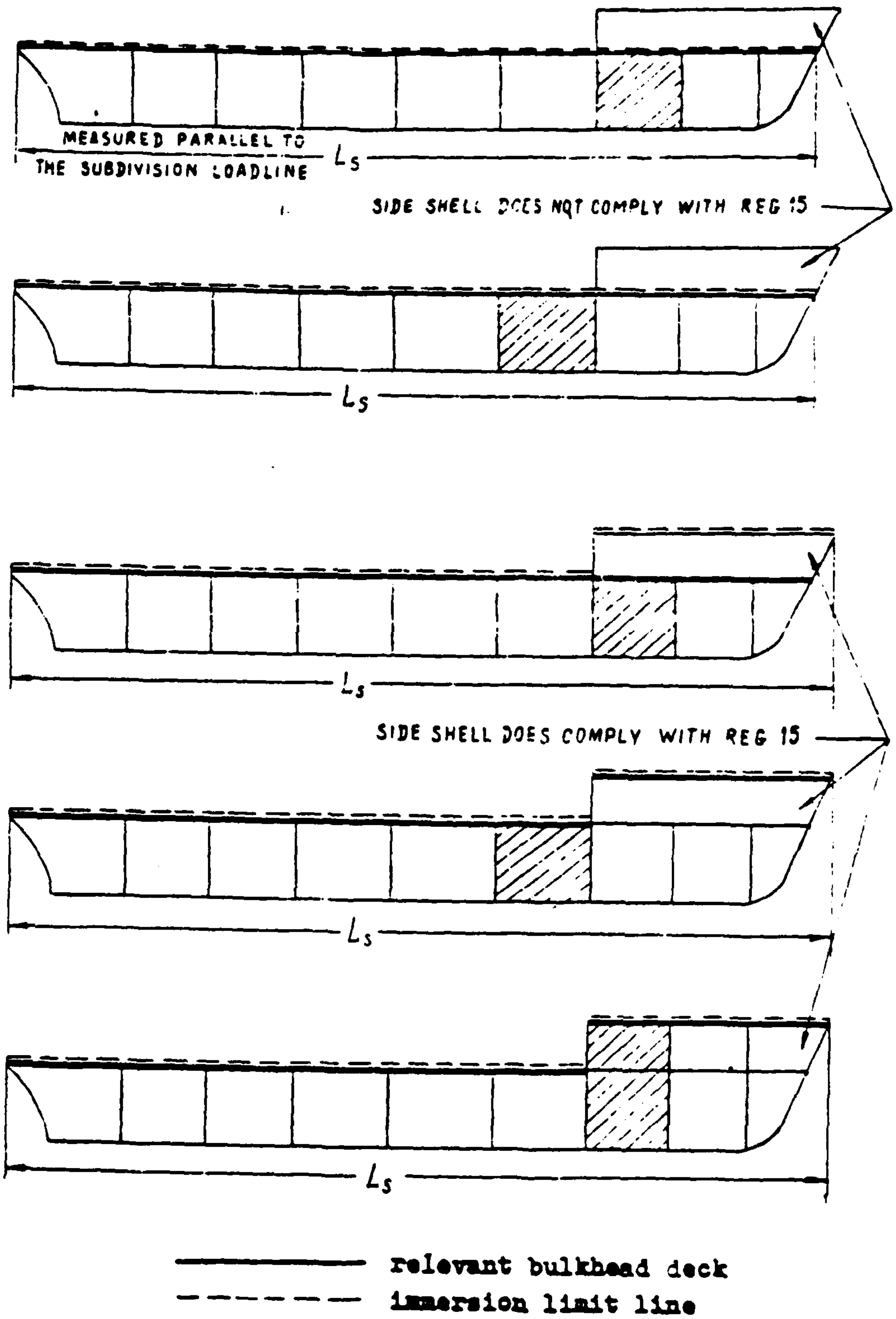
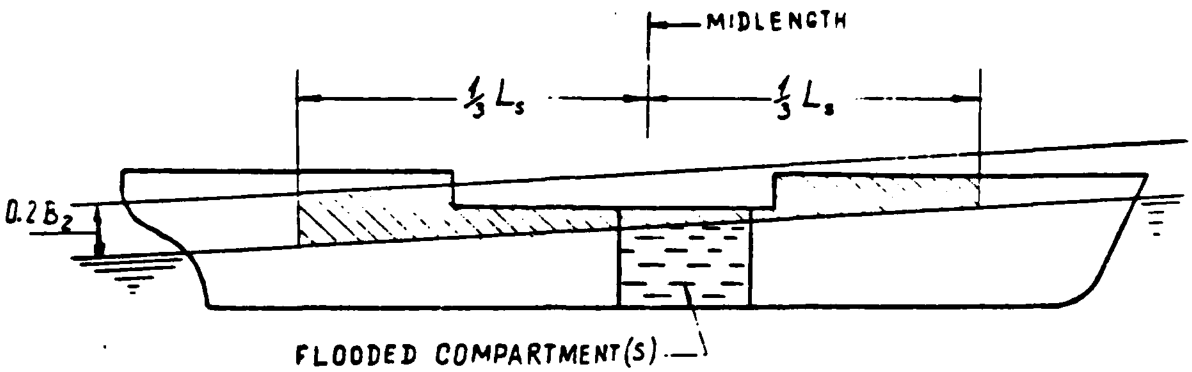


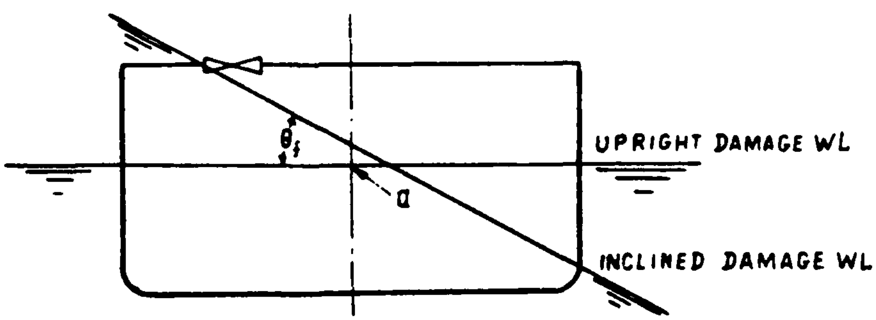
Figure 2.2(a) - Illustration of "effective mean damage freeboard" (F_1). Regulation 1(h)



$$F_1 = \frac{\text{AREA}}{\frac{2}{3} L_s}$$

The distance 0.2 B_2 may be measured perpendicular to the damage waterline, or perpendicular to the subdivision loadline. The difference is negligible for regulatory purposes.

Figure 2.2(b) - Illustration of limit on F_1 imposed by openings in the bulkhead deck.



The Administration may determine in each case if the inclined damage WL can be assumed to pass through the intersection point a, with negligible difference in θ_f.

F_1 shall not be taken as more than 1/3 B_2 tan θ_f where θ_f is the angle at which stairway or other openings in the bulkhead deck are immersed.

Paragraph 2(c). Formula (I) is based upon a consideration of the results of calculations of the Subdivision Index A for a representative sample of existing passenger ships complying with the requirements of the 1960 Safety Convention.

Because the Regulations in the 1960 Safety Convention under which these ships were constructed are illogical (for reasons stated in Part I) it would be surprising if these A values did not show considerable scatter.

After analyzing the characteristics of these ships and considering the influence of their essential design parameters, as well as the results of some design studies, it was concluded that, for new ships, A values appreciably better than attained by at least some of these existing ships, could be realized without economic or service penalty.

The coefficients of formula (I) were accordingly selected such that R corresponds to about the median of the attained A values of the entire sample, i.e., so as to correspond about to the average safety of existing ships. This is shown by Figure 2.3.[1/]

Paragraph 2(c), together with sub-paragraphs 5(b)(i) and (ii), retains a relationship between lifeboatage and compartment standard similar in intention to Regulations 1(d) and 5(e) of Chapter II of the 1960 Safety Convention. However, this new Regulation provides for a gradual increase in the safety standard in contrast to the abrupt increase which often results from application of the Regulations of the 1960 Safety Convention.

Paragraph 2(d) provides for relaxation of the safety standard at the discretion of the Administration and is analogous to Regulations 1(c), 5(e)(i)(2) and 5(e)(ii) of Chapter II of the 1960 Safety Convention.

1/ It should be mentioned that the points in this graph were obtained by means of the formulae used in previous draft regulations. However, it is considered that the difference in results after application of the latest formulae will not be significant.

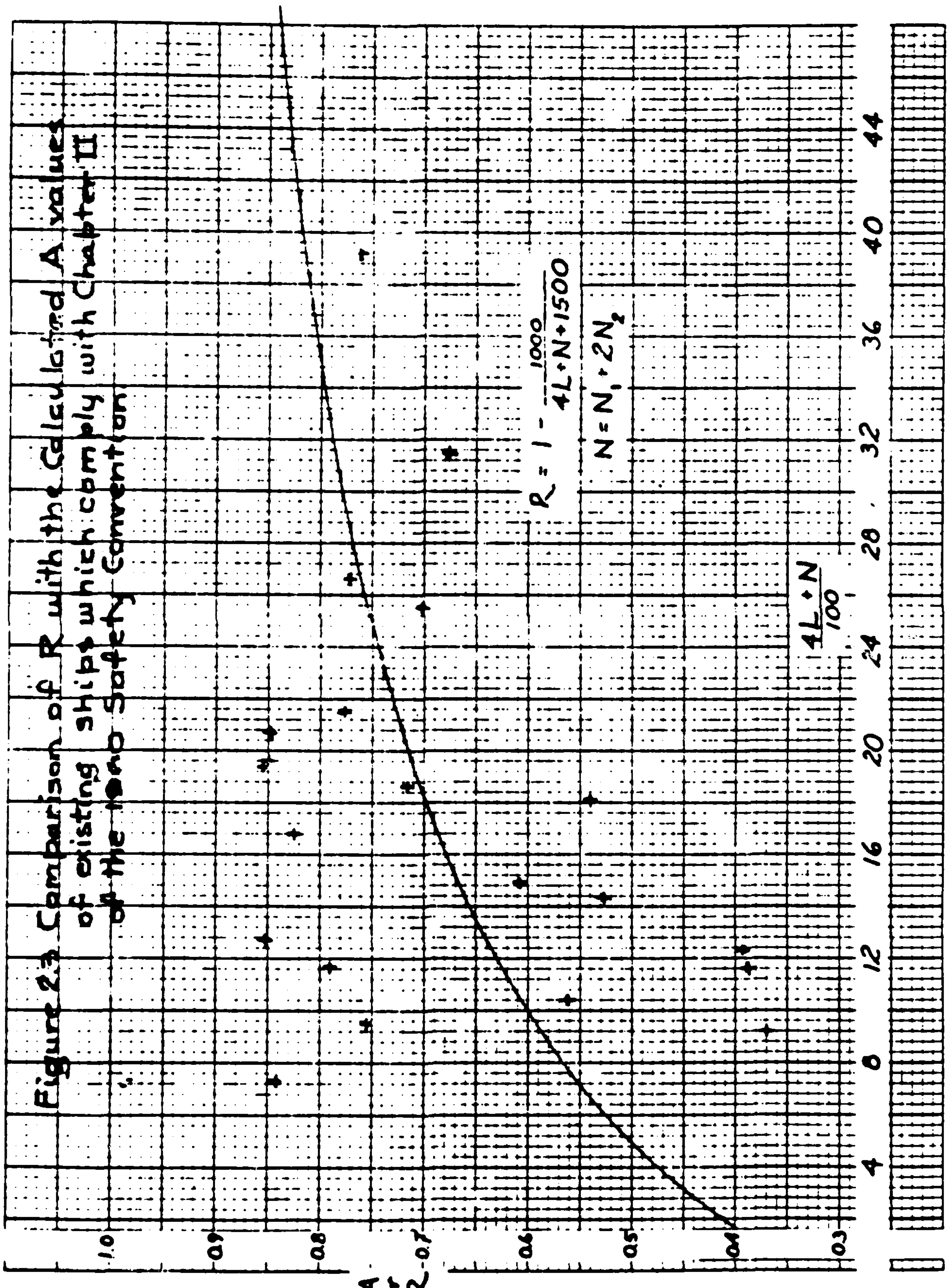


Figure 2.3 Comparison of R with the Calculated A values of existing ships which comply with Chapter II of the 1960 Safety Convention

Regulation 3 - Special Rules Concerning Subdivision

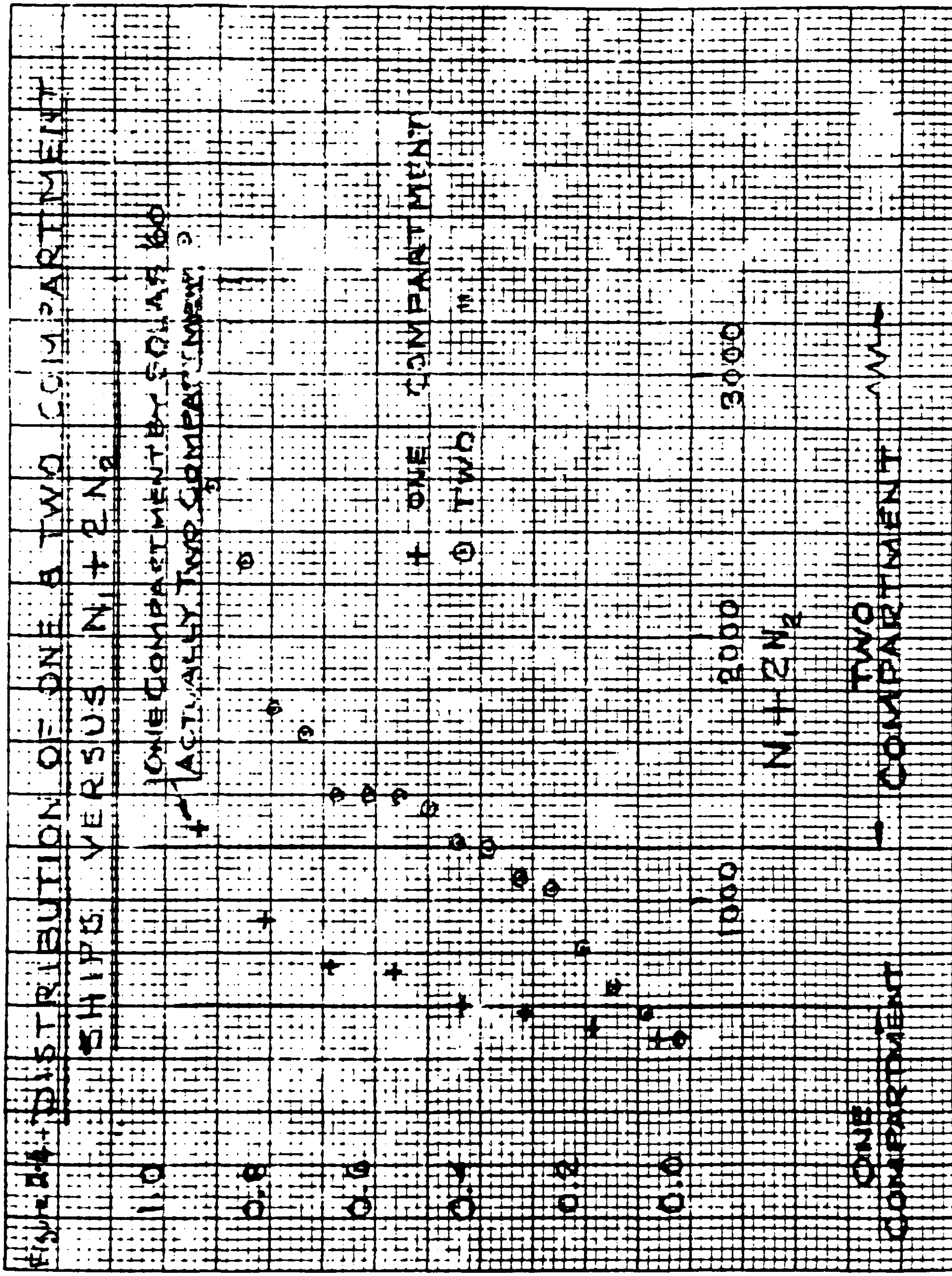
Paragraphs 3(a) and (b), in effect, take the place of Regulations 6(c) and (d) respectively of Chapter II of the 1960 Safety Convention.

Regulation 4 - Permeability

Paragraph 4(b) based upon analysis of actual ship operating data is logical. For ships having a small range of operating draughts (due appreciably if not entirely to variations in tankage), the likelihood is high that cargo spaces may be only slightly occupied or empty even when the ship is near d_s. On the other hand, for ships having a greater range of operating draughts, there is greater likelihood that some of this draught range will be due to variations in cargo and therefore that cargo spaces may be occupied by some cargo at any draught. At the same time, for any given ship, the possibility that cargo spaces may be only partially filled or even empty increases as operating draught is reduced.

Regulation 5 - Subdivision and Damage Stability

Studies of the subdivision and damage stability of existing long and short voyage ships, which comply with the 1960 Safety Convention, showed that there was no consistent relationship between ship length and the required compartmentation standard corresponding to the factor of subdivision. On the other hand, apart from scatter, it was found that Regulations 5(d) and (e) of Chapter II of the 1960 Safety Convention do roughly differentiate between one and two compartment ships according to the total number of persons aboard - as is shown in Figure 2.4. Consequently the compartment standard prescribed by this new Regulation is dependent upon N only as defined in Regulations 2(c) and (d) and already mentioned.


DISTRIBUTION OF ONE & TWO COMPARTMENT SHIPS VERSUS $N_1 + 2N_2$
ONE COMPARTMENT BY SOLAS 60
ACTUALLY TWO COMPARTMENT
+ ONE COMPARTMENT
⊖ TWO COMPARTMENT
1.0
0.8
0.6
0.4
0.2
0.0
1000
2000
3000
$N_1 + 2N_2$
ONE COMPARTMENT
TWO COMPARTMENT

Sub-paragraph 5(b)(i) provides that ships are as safe in respect to damages of the specified size as they are under Chapter II of the 1960 Safety Convention. Probabilistic evaluation of the effect of variation in damage size is dealt with by Regulations 6(c) and 7.

Sub-paragraphs 5(b)(i) and 5(b)(ii) have the effect of:

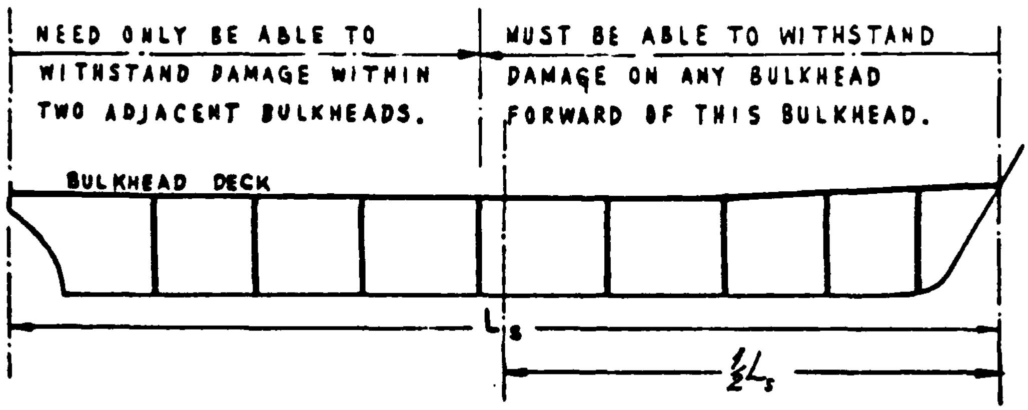
1. Requiring a one compartment standard for values of N for which nearly all sample ships have factor of subdivision values greater than 0.5.

2. Requiring, progressively, in addition a two compartment standard for part of the length forward for values of N for which some sample ships have a factor of subdivision greater than 0.5 while for other such ships the factor of subdivision is less.

3. Requiring a two compartment standard throughout for values of N for which nearly all sample ships have factor of subdivision values less than 0.5.

The method of application of sub-paragraph 5(b)(ii) is shown by Figure 2.5.

Figure 2.5 - Illustration of the Application of sub-paragraph 5(b)(ii) to a ship with N=900.



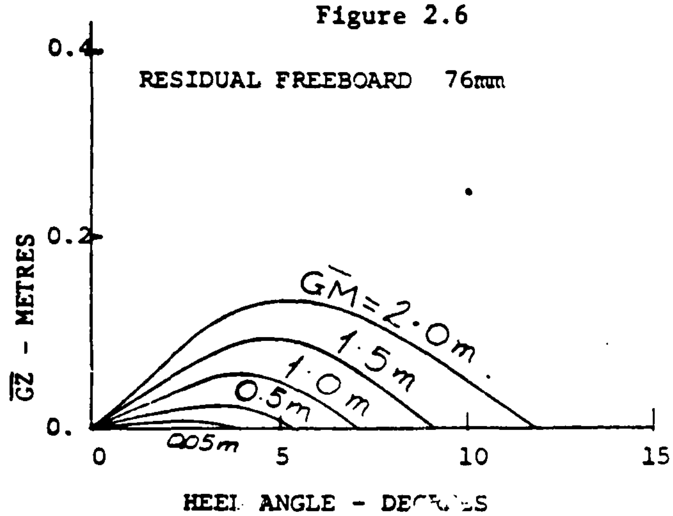
Two compartment standard is required for a proportion of the ship length abaft the forward terminal, given by

$$\left(\frac{N}{600} - 1 \right) L_s = \frac{L_s}{2} \text{ in this case.}$$

Sub-paragraph 5(b)(iii) has essentially the same intent as the corresponding Regulation 7(d)(iii) in the 1960 Safety Convention but is more explicit.

Sub-paragraph 5(c)(i) takes the place of Regulation 7(f) of Chapter II of the 1960 Safety Convention. Principally, it corrects the weakness in that Regulation which permits acceptance of conditions wherein a damaged ship simultaneously might have only 2 inches (or 0.05 metre) metacentric height and only 3 inches (or 0.076 metre) freeboard, or other unrealistically low values despite the fact that chances of surviving such a condition are, as is shown in Figure 2.6, non-existent.

Figure 2.6



GZ curves for a 100 m Vehicle Ferry.

The formulae for the minimum residual GM have the effect of providing:

(a) some allowance for a possible heeling moment due to an unsymmetrical distribution of persons on board; and

(b) an absolute minimum value of GM dependent on the beam and the freeboard after-damage.

Sub-paragraph 5(c)(i)(2) corrects the ambiguity of Regulation 7(f)(ii) of Chapter II of the 1960 Safety Convention and reflects the view of a majority of Sub-Committee Members that the maximum permissible heel for final flooding should be less than 15 degrees.

Sub-paragraph 5(c)(i)(3) in contrast to Regulation 7(f)(iii) of Chapter II of the 1960 Safety Convention eliminates any vertical limit to immersion within the flooded compartment or compartments, and prescribes that elsewhere in the ship the relevant bulkhead deck at side shall not be immersed. The Sub-Committee felt that a 3 inch (0.076 m) margin line, in association with the other provisions of these new Regulations, would be trivial and unnecessary.

Sub-paragraphs 5(c)(iii) and (iv) specify what may seem obvious - that heel before equalization or during any intermediate stage flooding shall not result in progressive flooding. That is to say, it may immerse the "relevant bulkhead deck" or even the "immersion limit line" but shall not immerse either deck or bulkhead openings through which extension of flooding can take place.

Sub-paragraph 5(c)(iv) leaves to Administrations to decide what stability may be sufficient during intermediate stages of flooding. However for purposes of uniformity in applying the Regulations, a minimum righting arm of 0.05 m may be recommended.

Reflecting the practice of Administrations with experience in dealing with this problem, the heel before equalization or at any intermediate stage is also limited to 20 degrees.

In regard to equalization time, it was found that the provision of Regulation 7(e) of Chapter II of the 1960 Safety Convention was interpreted differently. To avoid this ambiguity it was considered necessary to specify that the required equalization time relates to equalization to the limits specified in sub-paragraphs 5(c)(i)(2) and (3). At the same time, recognizing that equalization to complete equilibrium may take appreciably longer, it was considered that the time to attainment of those heel limits should not be more than 10 minutes.

Paragraph 5(d), together with sub-paragraph 5(b)(iii), defines the conditions and assumptions under which damage stability calculations are to be made and are much more explicit and unambiguous than the corresponding provisions of Chapter II of the 1960 Safety Convention.

The requirement concerning calculations dealing with equalization means that if a cross-connected side tank is damaged it shall be assumed to reach equilibrium with the sea prior to commencement of equalization. However, if there is sufficient free area through which water can flow such as lightening holes these provisions do not apply.

Regulation 6 - Attained Subdivision Index A

For the purposes of Regulation 6, except as provided in sub-paragraph 6(a)(iii), the specifications as to damage extent given in Regulation 5 do not apply. However, the longitudinal extent of damage and related extent of flooding used in calculating a, p and s should be mutually consistent and the vertical extent of damage used for purposes of formula (VIII), should be that resulting in the least value of s.

Under sub-paragraphs 6(a)(ii) and 6(d)(iii), even for a ship required by Regulation 5 to be built to one compartment standard, if the placing of bulkheads and draught and trim are such that in a part of the length, it is possible to obtain an "s" value more than zero after flooding of two or more adjacent compartments under the conditions specified therein, the contribution of such a flooding condition to the Σ aps may be included.

In circumstances where sub-paragraph 6(a)(iii) applies, the additional contribution due to damage penetrating into the inboard spaces may also be included. In such case formula (II) becomes:

$$A = \Sigma\, ap[s_w r + s_c(1-r)]$$

where s_w = s after flooding of only wing compartments

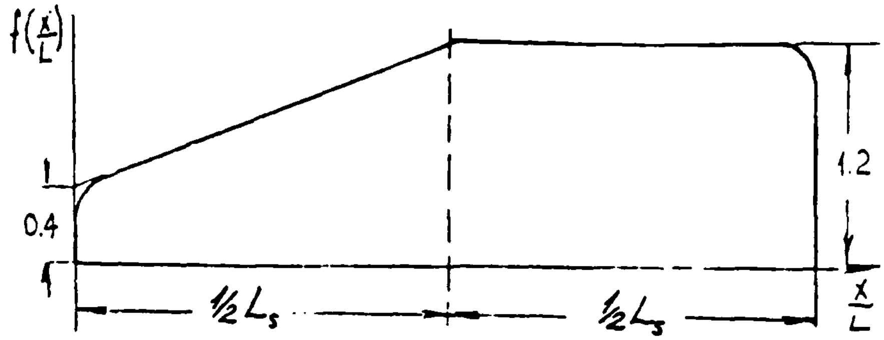
s_c = s after flooding of both wing and inboard compartments.

Whether or not sub-paragraph 6(a)(iii) applies, damage may be assumed as limited to only wing spaces if "p" is taken as multiplied by "r".

Paragraphs 6(b) and (c) contain formulae (III) and (IV) which are based upon an analysis of collision casualty data.

Formula (III) in effect assumes a damage density distribution along the ship length approximately as shown in Figure 2.7.

Figure 2.7



Formula (IV), in effect, assumes for ships up to 200 metres L_s, that damages which may occur will vary from 0 to 0.24 L_s in longitudinal extent with a median longitudinal extent of about 0.07 L_s. For ships above 200 metres L_s it assumes that the longitudinal extent of damage varies between 0 and 48 metres and with a median longitudinal extent of about 14 metres.

Figure 2.8 illustrates the definitions of p and l as used in Formulae (III) and (IV).

Paragraph 6(d). Formula (VIII) given in sub-paragraph (i) is an empirical expression of the form

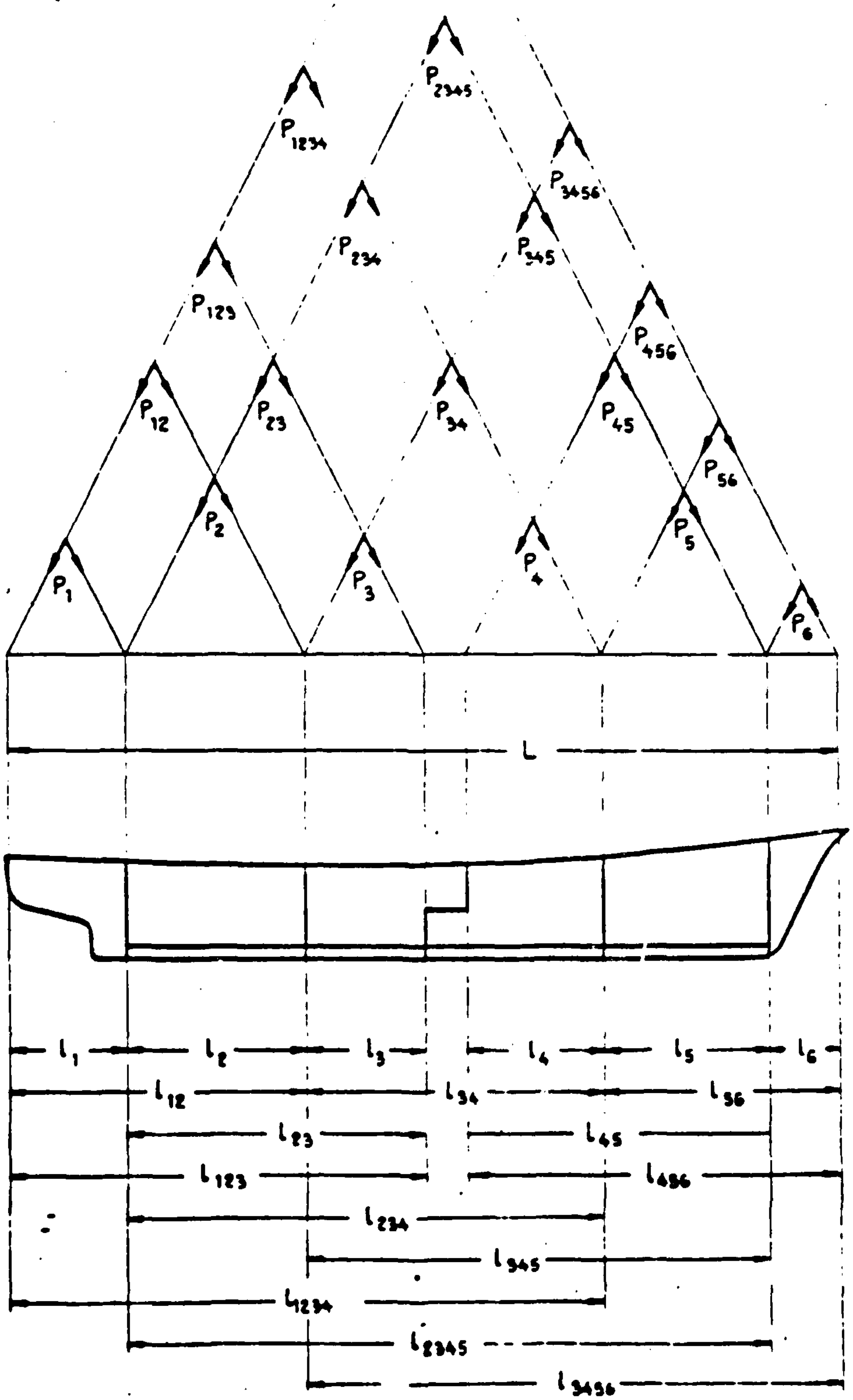
$$s = \left[\frac{F_e \, GM_e}{B_2}\right]^{0.5}$$

where: $F_e = F_1 - \frac{B_2}{2} \tan \Theta$, is the effective freeboard flooded;

$GM_e = GM_R - MM_S$, is the effective metacentric height flooded; and

s is the probability of survival factor.

FIGURE 2.8


P2345
P1234
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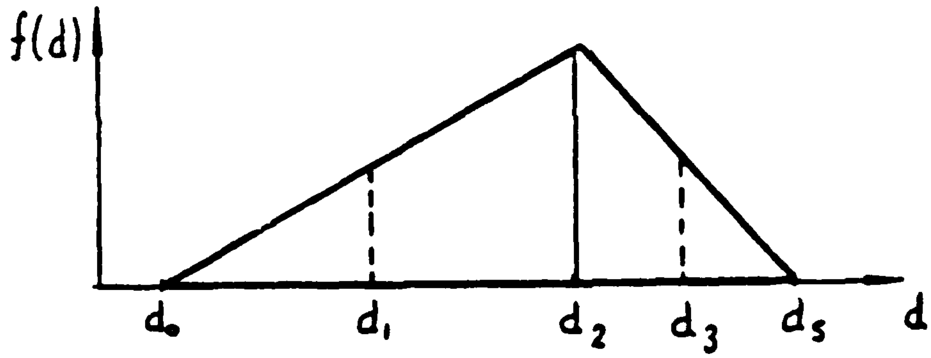
l1234
l2345
l3456

This expression is based upon the results of damage stability model experiments in waves and upon consideration of probable collision casualty sea state as indicated by sea condition reports of collided ships.

The multipliers of Formula (IX) of sub-paragraph 6(d)(ii) in effect give "s" as obtained by a Simpson's integration over the range of draughts between d_o and d_s when the density function of draught distribution is taken as triangular, with the maximum value at d_2 and with values at d_1 and d_3 half the maximum. That is to say, d_2 is assumed to be most likely and d_1 and d_3 are assumed each to be half as likely, as shown in Figure 2.9

Figure 2.9



The use of this assumed draught distribution function is based upon examination of the ship operating data also considered in respect to variations in cargo space permeability (already discussed).

Regulation 7 - Combined Longitudinal and Transverse Subdivision

Except as provided in Regulation 6(a)(iii), Regulation 7 need not be applied to conventional ships in which the transverse bulkheads extend from side to side.

Regulation 7 provides a means for evaluating the safety of ships wherein the spacing of transverse bulkheads bounding the space or spaces inboard of longitudinal watertight bulkheads may appreciably exceed that of the transverse

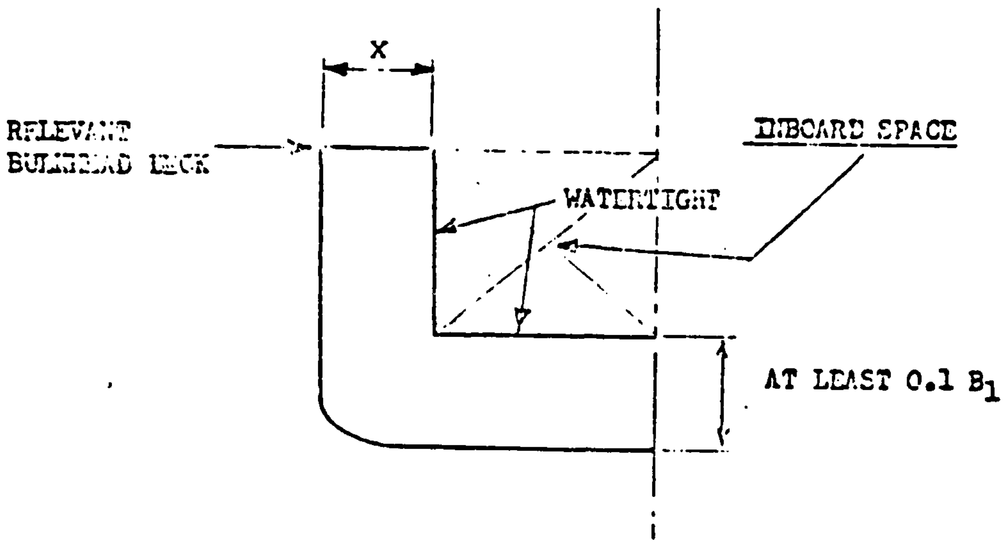
watertight bulkheads separating the outboard compartments. For instance, subject to compliance with Regulation 5, and provided that the resulting "A" value, calculated according to Regulation 7(b), is at least equal to "R", Regulation 7 permits acceptance of a design having a very long inboard space above a watertight flat or deck which must be at least $0.1B_1$ above the base line but may be below the subdivision load line. It may be noted that such a design is not acceptable under the Regulations of Chapter II of the 1960 Safety Convention. Regulation 7, therefore, has the effect of permitting designers improved latitude to adopt more efficient arrangements in respect to a ship's service needs. It is anticipated that this Regulation will have particular application to vehicle ferries.

This Regulation, in effect is predicated on the assumption that flooding of inboard spaces, if it occurs at all, will be due only to side damage penetrating that deep. This assumption is justified by the requirement of sub-paragraph 7(a)(i) for a horizontal watertight division not less than $0.1B_1$ above the base line, which virtually assures that flooding of inboard spaces as a result of bottom damage is very unlikely.

The reduction factor "r" given by Formula (X) is based upon examination of collision cases in which information on both damage penetration and damage longitudinal extent was available. While damages of greatest longitudinal extent are caused by glancing impacts and therefore tend to have shallow penetration, examination of the collision cases showed that in most cases, greater longitudinal extent was associated with greater penetration - that is to say, collisions involving greater energy absorption. The formulae for "r" reflects this relationship.

Figure 2.10 illustrates the applicable limits as regards to ship arrangement and Figure 2.11 illustrates the definitions of l and b according to sub-paragraph 7(b)(ii).

Figure 2.10

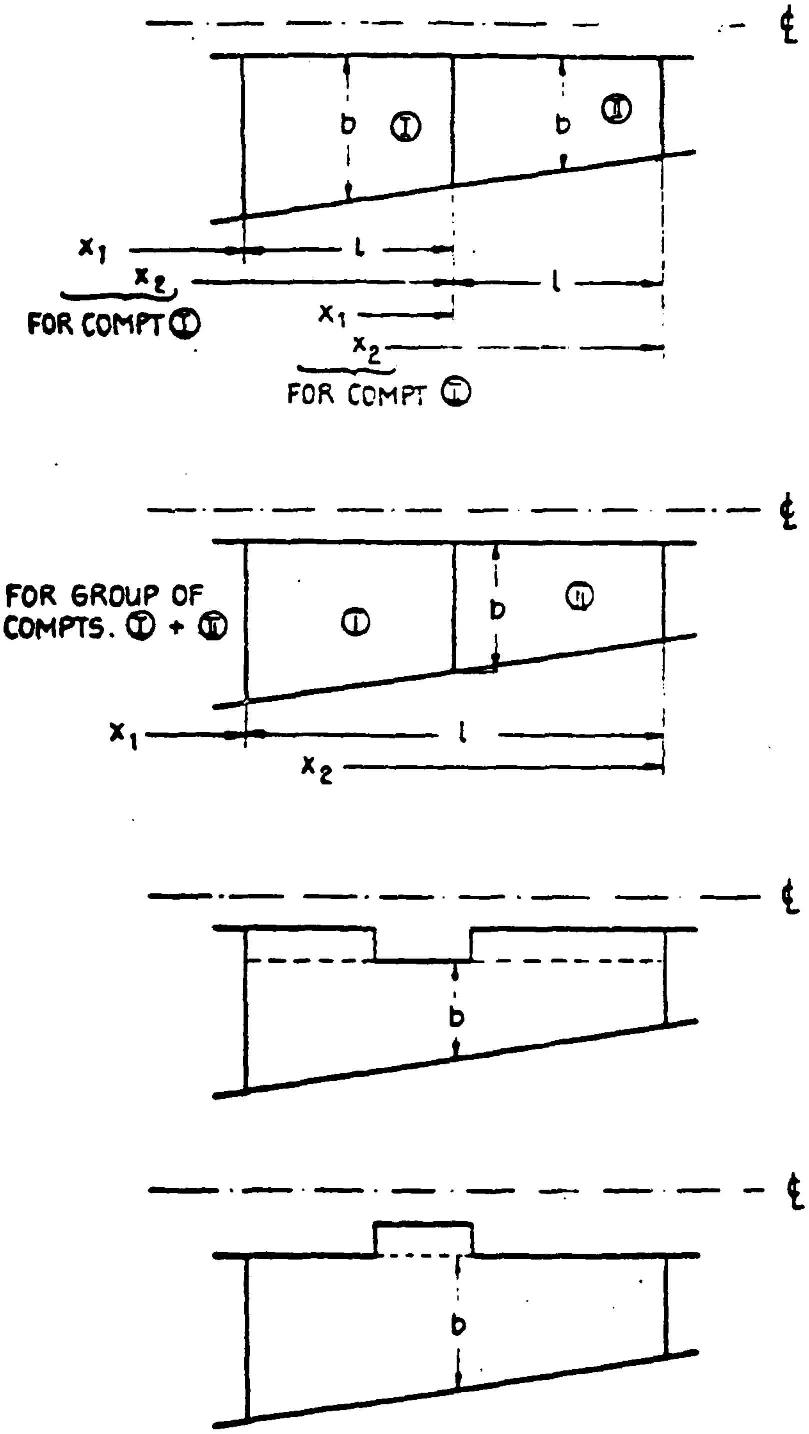


"X" is the least distance measured at right angles to centreline, from ship's side, at level of subdivision load line, to longitudinal bulkhead.

If "X" is <u>not less than</u> 0.2 B_1 and "A" computed by Regulation 7(b) at least equals "R", possible damage to inboard space may be disregarded and inboard space does not require subdivision.
If however "A" computed in accordance with Regulation 7(b) is less than "R", the possibility of damage to the inboard space may be included. In such a case, the inboard space must be subdivided sufficiently so that the resultant flooding does not exceed the sinkage, trim and heel limits of Regulation 6(d)(iii).

If "X" is <u>less than</u> 0.2 B_1 damage to the inboard space must be assumed and such inboard space must be subdivided sufficiently so that the resultant flooding does not exceed the sinkage, trim and heel limits of Regulation 5(c).

FIGURE 2.11



DEFINITION OF b

Regulation 8 - Stability Information

Regulation 8 replaces those portions of Regulations 7(e) and (g) of Chapter II of the 1960 Safety Convention dealing with information to the Master, Regulation 19 as it applies to passenger ships, and Regulation 20. In so doing, Regulation 8 more specifically indicates the nature and extent of the required information. The new Regulations accordingly do not include the relaxation provision as contained in Regulation 7(h) of Chapter II of the 1960 Safety Convention.

Regulations 9-21

Regulations 9 to 21 replace Regulations 8 to 18, 21 and 22 of Chapter II of the 1960 Safety Convention, with amendments as necessary for consistency with Regulations 1 to 8. In general, these amendments do not materially change the level of requirements provided by the Regulations in Chapter II of the 1960 Safety Convention.

PART III - GUIDANCE FOR ASSEMBLING INPUT DATA AND STRUCTURING OUTPUT DATA

The information given in this part of the explanatory note is intended for assistance to practising naval architects in planning and in making the calculations necessary to comply with the new Subdivision and Damage Stability Regulations. Also included is a flow diagram relative thereto.

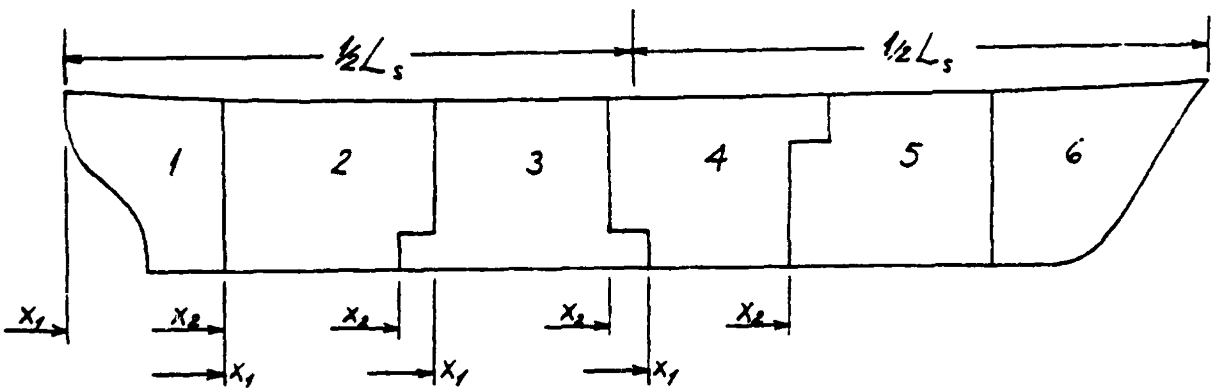
Input data

The input data fall into three categories, some measured directly from the ship's plans, the remainder calculated.

1. Data measured directly from the ship's plans.

(a) L_s, "midlength", B_1, B_2, N_1, N_2, N, X_1, X_2, d_o and d_s. As can be seen from Figure 3.1, X_1 and X_2 for each compartment must be chosen so that the difference $(X_2 - X_1)$ is a minimum.

Figure 3.1



(b) Data for the relevant bulkhead decks, probably in the form of sets of co-ordinate points along the decks comprising the relevant bulkhead decks for each compartment damage case. An index for each co-ordinate point could be used to associate the relevant bulkhead deck with each damage case.

(c) Openings leading to downflooding, which could be indexed similarly. Openings leading to flooded compartments would be disregarded for particular damage cases.

(d) Permeabilities for all but cargo spaces and tanks, established by Regulation 4(a).

2. Information for intact ship loading conditions

(a) d_1, d_2, and d_3, calculated from formulae in Regulation 3(g)(iii).

(b) Maximum trims anticipated at each draft (d_o to d_s). The damage stability calculations should be performed so that maximum forward trims will be used with damages to the forward part of the ship, and maximum aft trim will be used with damages to the aft part of the ship. This assumption will provide the most onerous conditions regarding the relevant bulkhead decks or downflooding openings.

(c) μ_i for cargo spaces, calculated in accordance with Regulation 4 (b) or 4 (c).

3. Damage specifications

(a) All one and two compartment damages, as required for Regulation 5, and all additional combinations desired for inclusion in the calculations for "A". For the convenience of naval architects, it is suggested that a systematic numbering system be applied to the combinations of compartments. A sample of such a system is : 10.32. The integer refers to the aftmost damaged compartment, the first decimal number refers to the number of compartments included (10, 11, 12), and the second decimal number refers to alternative floodings for the same main compartments (10.31 refers to damage including a double bottom, 10.32 refers to damage above the double bottom).

(b) Items for each damage case:

(i) compartments or combinations to be flooded.

(ii) permeabilities of tanks (0.00 or 0.95) must be assumed, to provide the more onerous damage condition for Regulation 5.

(iii) index for relevant bulkhead deck (see 1(b)) to be used for calculation of F_1, and for satisfaction of Regulation 5(c)(i)(3) or 6(d)(iii)(2).

(iv) index for downflooding openings which are associated with the damage case.

(v) information controlling the processes of intermediate stages of flooding and cross-flooding.

Output data

For the sake of having uniform presentations of the data from various naval architects, the following outline is recommended:

(a) Summary of results: GM_R for each intact loading condition, with the associated draft and trim, and the "A" value. Also included: GM_R values if higher than those required in Regulation 5 and the resultant "A" value.

(b) Tables of data to fulfil Regulations 5 and 6, according to the following criteria:

(i) relevant bulkhead deck clear of the flooded compartments not immersed in the final stage of flooding.

(ii) angle of heel not exceeding 20° during flooding.

(iii) no progressive flooding during flooding.

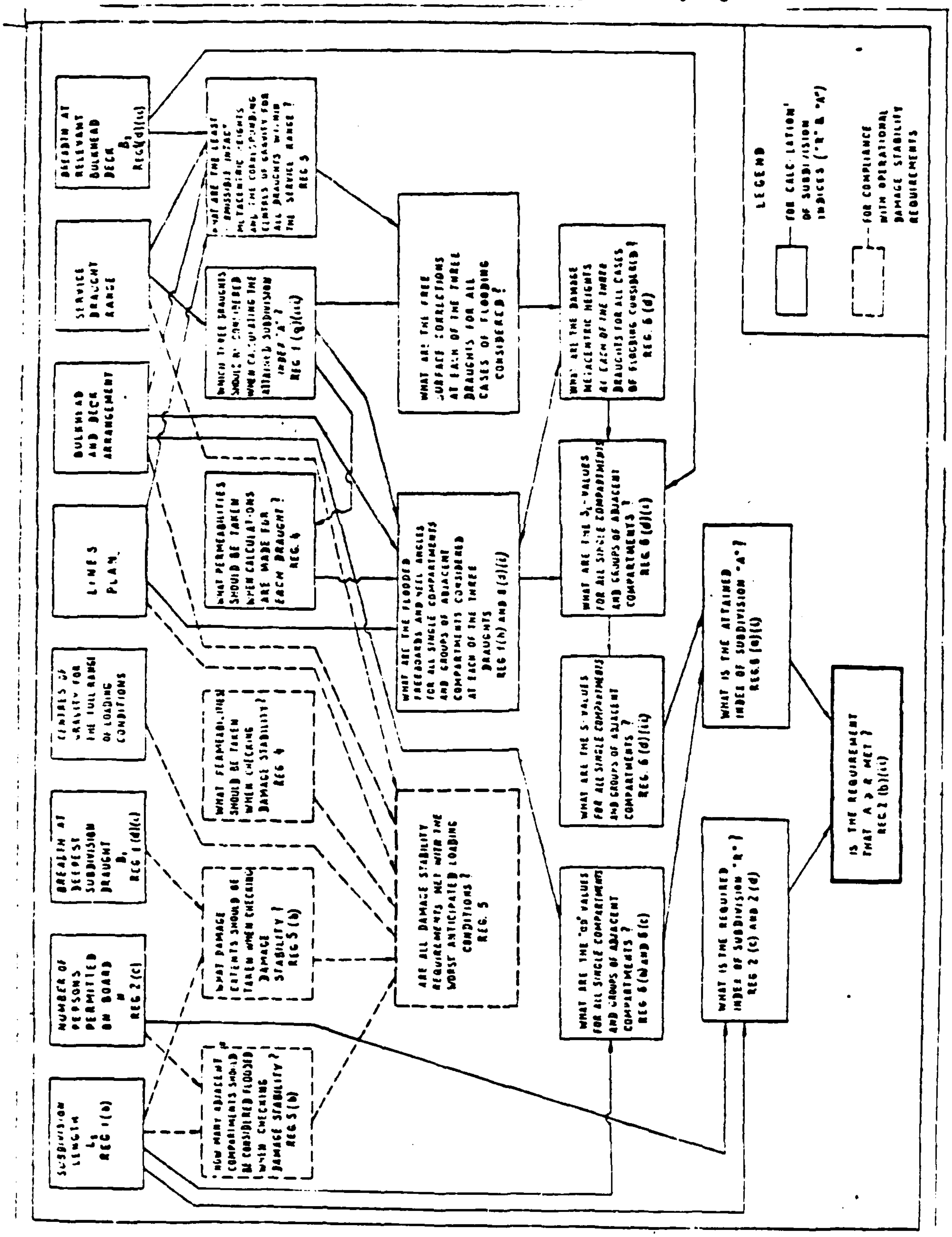
(iv) angle of heel limited to 7° for one-compartment damage and 12° for two-or-more-compartment damage in final stage of flooding.

(v) GM in final stage of flooding not less than
$0.003 \cdot B_2^2 \cdot (N_1 + N_2)/(\text{displacement} \cdot F_1)$ or
$0.015 \cdot B_2/F_1$ or 0.05, in metres (for Regulation 5).

(vi) (GM_R-MM_S) in final stage of flooding not less than 0.05 metres (for Regulation 6(d)(iii)).

(c) Tables of data for individual damage cases. The administrations probably will require data for righting arm curves, in accordance with Regulation 5(c)(iv). They probably also will require data for the minimum distances from the flooded waterlines to the relevant bulkhead decks and to the relevant downflooding openings.

Figure 3.2 - Flow diagram for calculations in accordance with the new subdivision and damage stability regulations



PART IV - BASIS FOR THE CALCULATION OF THE SUBDIVISION INDEX A

In this part the physical and statistical background of the subdivision index is presented. The calculation of the probability of damage is developed and a summary of the damage data statistics is given.

Finally, the development of the calculation of the probability that a damaged ship will not capsize or sink is demonstrated.

1. Introduction

The Attained Subdivision Index A is based on the concept of the probability of survival of the ship in case of collision.

In order to develop this concept it is assumed that the ship is damaged. Since the location and size of the damage is random, it is not possible to state which part of the ship becomes flooded. However, the probability of flooding of a space can be determined if the probability of occurrence of certain damages is known: the probability of flooding a space is equal to the probability of occurrence of all such damages which just open the considered space. Thereby a space is a part of the volume of the ship which is bounded by undamaged watertight structural divisions.

Next it is assumed that a certain space is flooded. In addition to some invariable characteristics of the ship, whether the ship can survive flooding depends, in such a case, on the initial draught and GM, the permeability of the space and the weather conditions, which are all random at the time when the ship is damaged. Provided that the limiting combinations of the aforementioned variables and the probability of their occurrence are known, the probability that the ship with the considered space flooded will not capsize or sink can be determined.

The probability of survival is the sum of the products for each compartment or group of compartments of the probability that a space is flooded multiplied by the probability that the ship will not capsize or sink with the considered space flooded.

Although the ideas outlined above are very simple, their practical application in an exact manner would give rise to several difficulties. For example, for an extensive but still incomplete description of the damage its longitudinal and vertical location as well as its longitudinal, vertical and transverse extent is necessary. Apart from the difficulties in handling such a five-dimensional random variable, it is impossible to determine its probability distribution with the presently available damage statistics. Similar conditions hold for the variables and physical relationships involved in the calculation of the probability that a ship with a flooded space will not capsize or sink.

In order to make the concept practicable, rather extensive simplifications are necessary. Although it is not possible to calculate on such a simplified base the exact probability of survival, it is possible to develop a useful comparative measure of merit of the longitudinal and transverse (but not horizontal) subdivision of ships.

2. Determination of the Probability of Flooding of Ship Spaces

(a) Consideration of longitudinal damage location and extent only.

The simplest case is to consider only the location and length of damage in longitudinal direction. This would be sufficient for ships with no longitudinal and horizontal watertight structural divisions.

With the damage location x and damage length y as defined in Figure 4.1, all possible damages can be represented by points in a triangle which is also shown in this figure.

All damages which open single compartments of length l_i are represented in Figure 4.1 by points in triangles with the base l_i. Triangles with the base $l_i + l_j$ (where $j = i + 1$) enclose points corresponding to damages opening either compartment i, or compartment j, or both of them. Correspondingly, the points in the parallelogram ij represent damages which open both the compartments i and j.

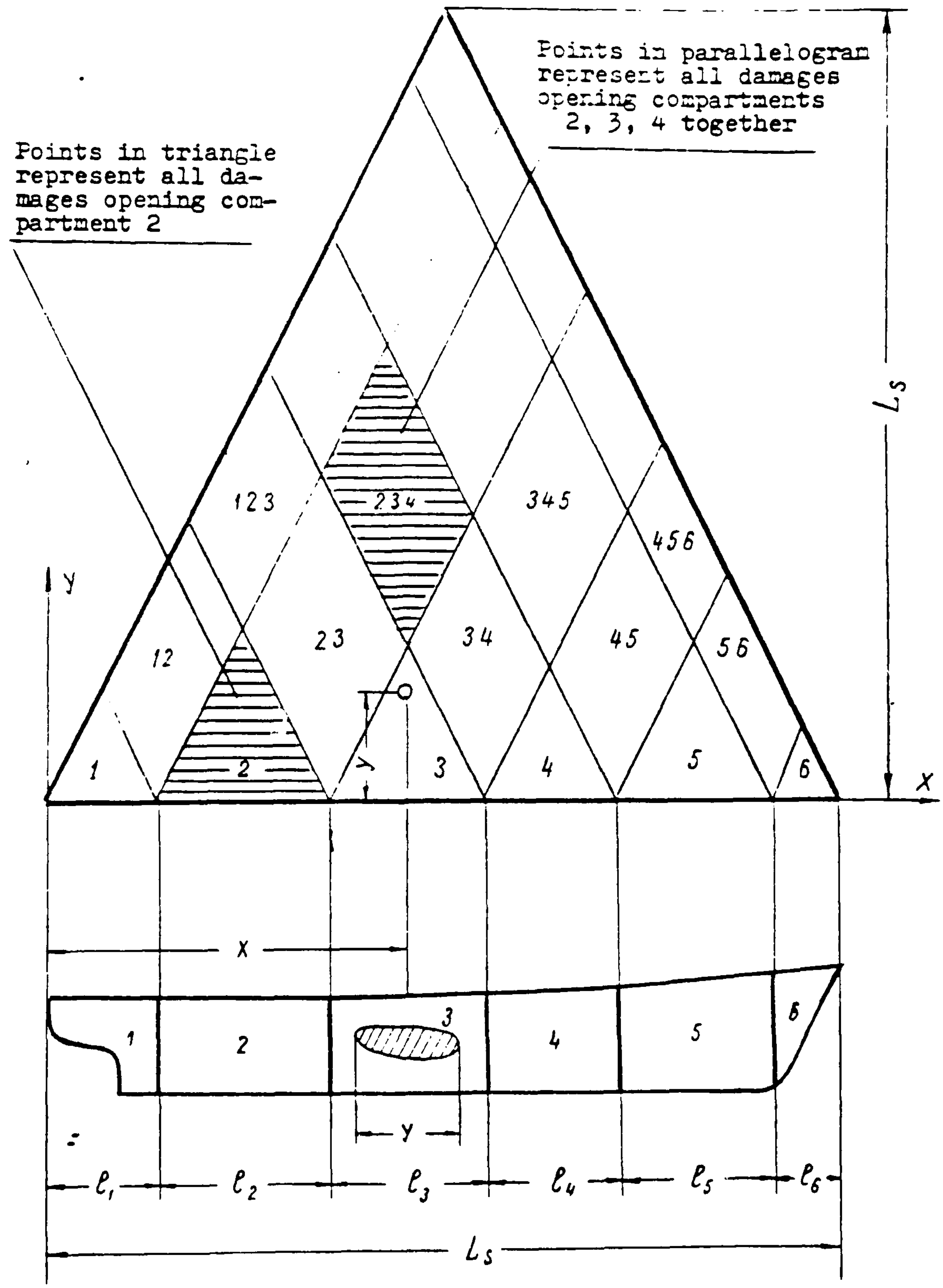

Points in parallelogram represent all damages opening compartments 2, 3, 4 together
Points in triangle represent all damages opening compartment 2
y
123
234
345
456
12
23
34
45
56
1
2
3
4
5
6
x
L_s
x
1
2
3
4
5
6
y
ℓ_1
ℓ_2
ℓ_3
ℓ_4
ℓ_5
ℓ_6
L_s

Figure 4.1

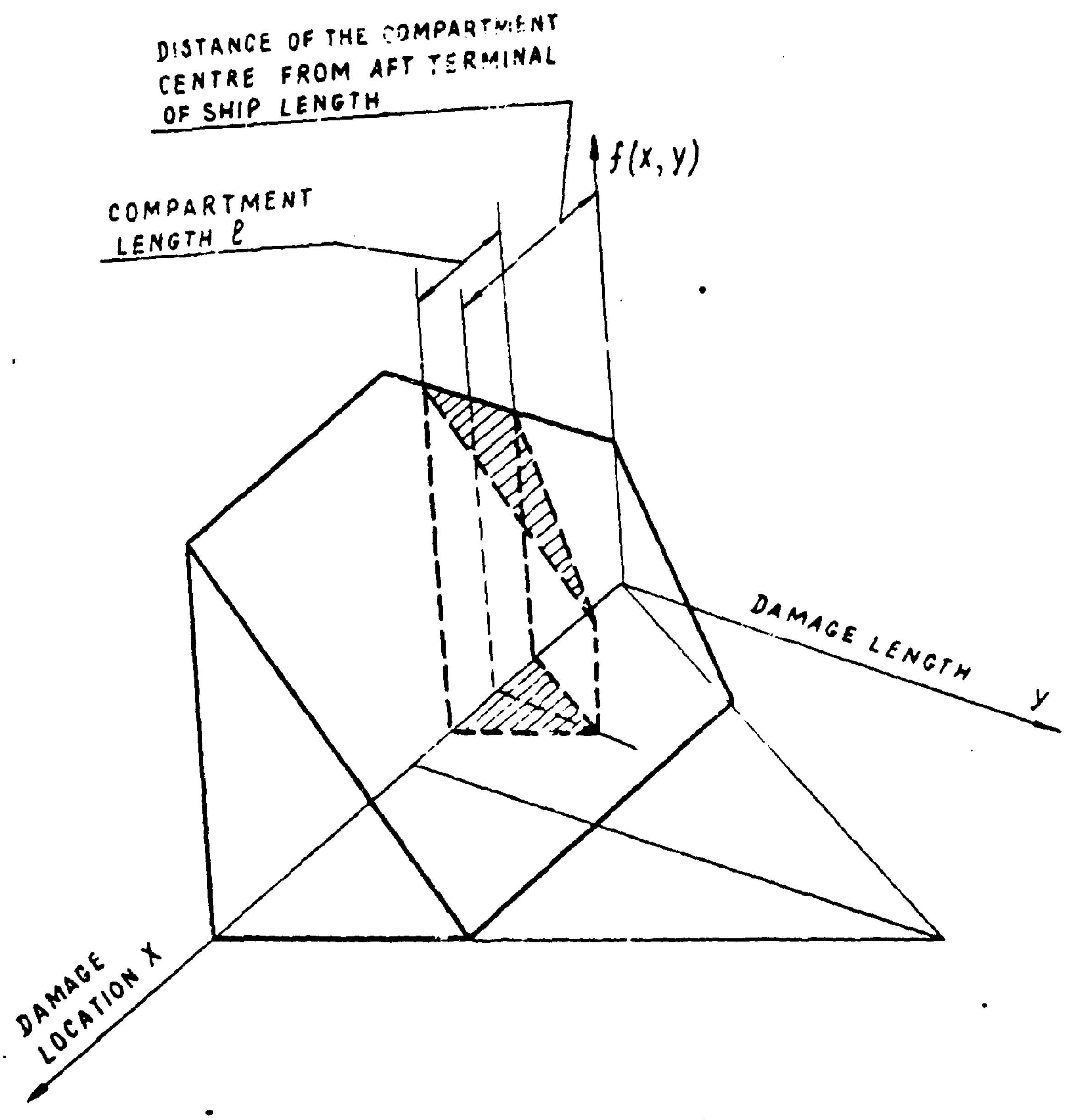

DISTANCE OF THE COMPARTMENT CENTRE FROM AFT TERMINAL OF SHIP LENGTH
f(x, y)
COMPARTMENT LENGTH ℓ
DAMAGE LENGTH
y
DAMAGE LOCATION X

FIGURE 4.2

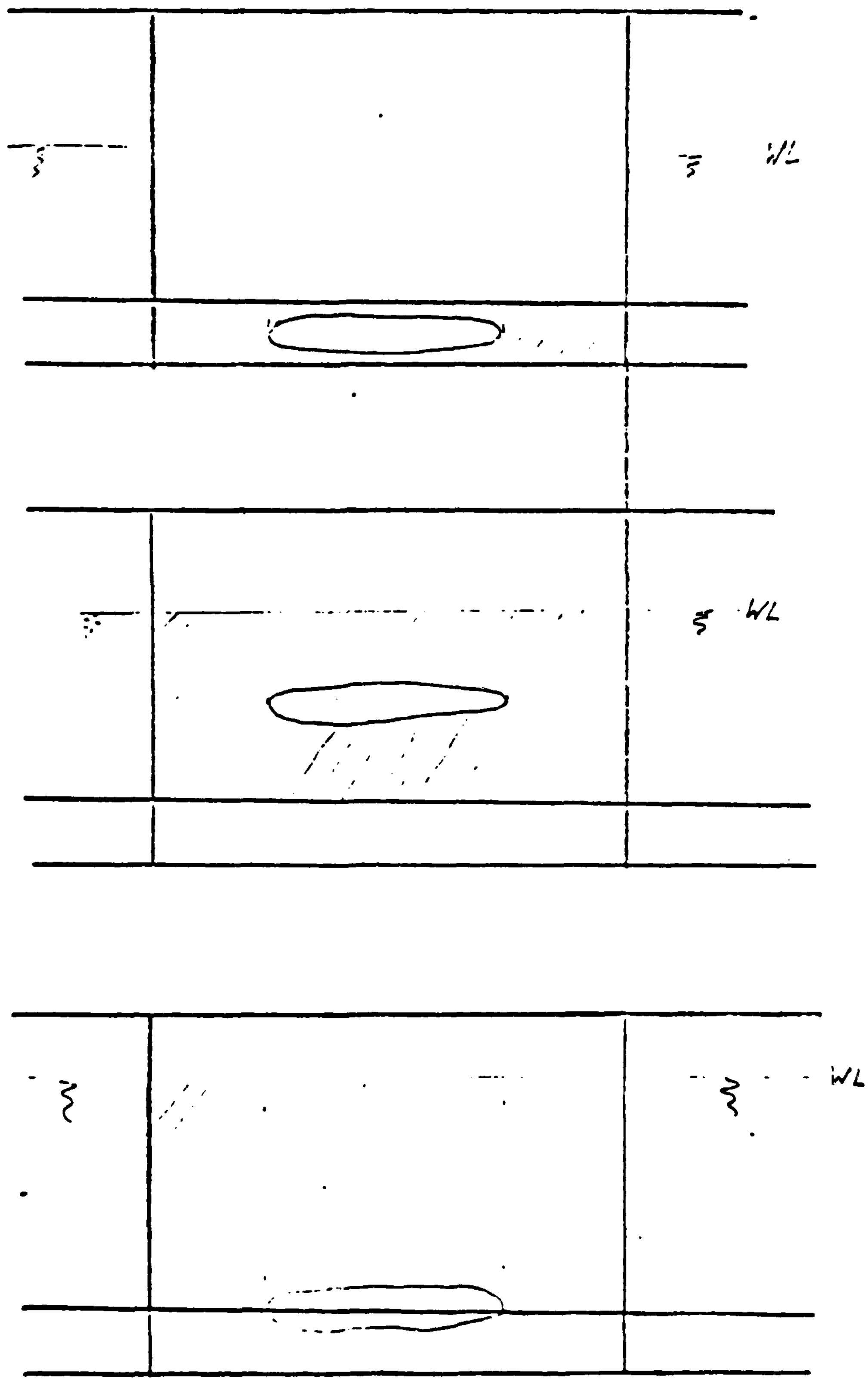
Damage location x and damage length y are random variables. Their distribution density f(x,y) can be derived from the damage statistics. The meaning of f(x,y) is as follows (see Figure 4.2): the total volume between the x-y plane and the surface given by f(x,y) equals one and represents the probability that there is damage (this has been assumed to be certain). The volume above a triangle corresponding to damages which open a compartment represents the probability that this compartment is opened. In similar manner for all areas in the x-y plane which correspond to the opening of compartments or groups of compartments there are volumes which represent the probability that the considered compartments or group of compartments are opened.

The probability that a compartment or group of adjacent compartments is opened can be expressed as a.p., where a and p are to be calculated according to the formulae given in Regulation 6 (formulae (II) to (VII)) of the new Regulations.

Consideration of damage location x and damage length y only would be fully correct in the case of ships with pure transverse subdivision. There are, however, no such ships, they have at least a double bottom. In such a case the probability of flooding a compartment should be split up into the following three components: probability of flooding the double bottom only, probability of flooding the space above the double bottom only and probability of flooding both the space above and the double bottom (see figure 4.3). For each of these cases there may be a different probability that the ship will survive in flooded condition. A way out of this dilemma, which has to be used in applying the new regulations, is to assume that the most unfavourable vertical extent of damage (out of the three possibilities) occurs with the total probability a.p. Therefore the contribution to survival probability made by more favourable cases is neglected. That the concept is still meaningful for comparative purposes follows from the fact that the error made by neglecting favourable effects of horizontal subdivision is not great and the more important influence of longitudinal damage location and extension is fully covered.

Some examples for dealing with other cases of horizontal subdivision are given in Appendix I.

Figure 4.3



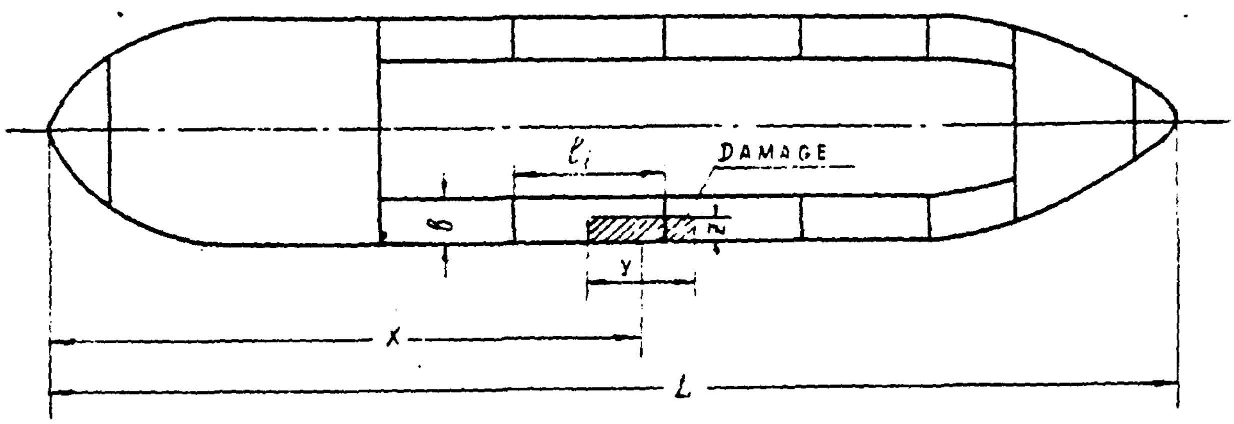


FIGURE 44

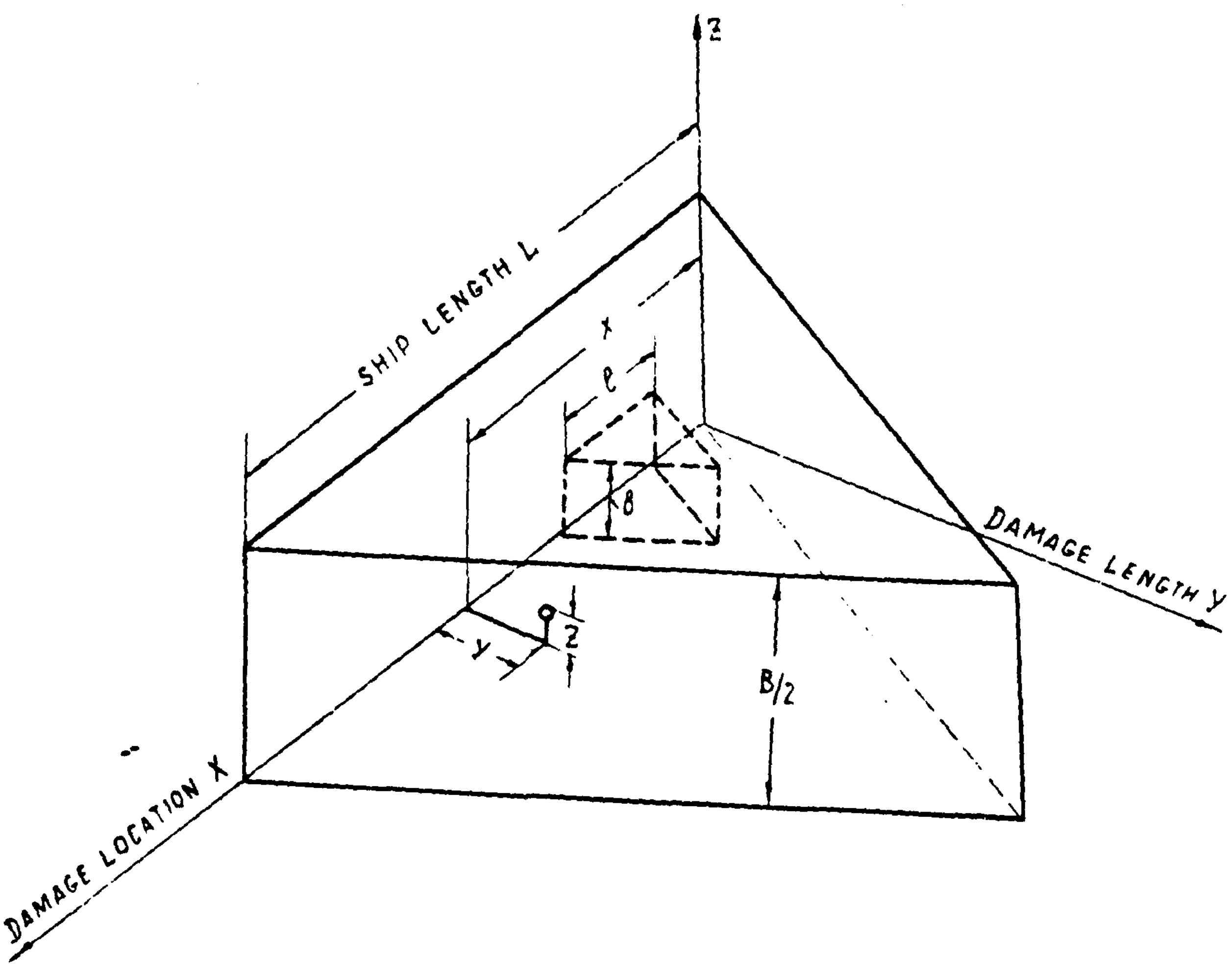


FIGURE 45

(b) Consideration of damage penetration in addition to longitudinal damage location and extent.

With the simplifying assumption that the damage is rectangular and neglecting again its vertical extent, it can be described by the damage location x, the damage length y and the damage penetration z (see Figure 4.4). These variables can be represented in a three dimensional coordinate system as shown in Figure 4.5. Each point in the prism with triangular base represents a damage. All damages which open a side compartment correspond to the points of a smaller prism with height b equal to the distance of the longitudinal bulkhead from the ship side, which is erected above a triangle with the base l_i equal to the length of the considered side compartment. It is not difficult to identify in Figure 4.4 the volumes which correspond to such damage which flood other parts of the ship bounded by transverse and longitudinal watertight structural subdivisions.

Damage location x, damage length y and damage penetration z are random variables. The distribution density f(x,y,z) can be derived from the damage statistics. This distribution density can be illustrated by assuming it to be a density which varies from point to point of the volume shown in Figure 4.5. The "weight" of the total volume is one and represents the probability that there is a damage (which is assumed to be certain). The weight of a partial volume (representing the flooding of certain spaces) represents the probability that the considered spaces are opened.

The probability that a side compartment is opened can be expressed as a.p.r., where a and p are to be calculated according to formulae (II) to (VII) of Regulation 6 and r according to formula (X) of Regulation 7 of the new Regulations. The probability that a centre compartment in addition to a side compartment is opened can be expressed as a.p.(1 - r).

Some examples for the calculation of the probability that side or side and centre spaces are opened are given in Appendix II.

Again it is to be stated that the probability calculated on the base of the simplifying assumption mentioned before is not exact. Nevertheless it

gives a comparative measure of how the probability of opening spaces depends on transverse and longitudinal structural subdivisions, which takes account of the most essential influences and neglects secondary effects only. Neglecting the random variation of longitudinal and transverse damage extent would be a much graver error than that which is caused by neglecting secondary effects.

3. Damage Statistics

(a) Source of data.

The following considerations are based on the information contained in various IMCO documents. They summarize casualty data reported to IMCO on 811 damage cards. There are 296 cases of rammed ships which contain information on each of the following characteristics:

Ship length L
Ship breadth B
Damage location x
Damage length y
Damage penetration z.

In order to omit inconsistencies of the results derived from the data, which may be caused by the use of different samples, the following investigations have been based only on the aforementioned 296 cases. However, additional investigations have been made using also the information given for other cases. Despite the random scatter which is to be expected because of the use of different samples composed in random, they lead to the same conclusion.

For the investigation of the dependency of damage length on the year of collision a different sample, including 209 cases in which L, y and year of collision are given, had to be used.

(b) General considerations on damage extensions.

Common sense dictates that damage extent depends on:

(i) structural characteristics of the rammed ship;

(ii) structural characteristics of the ramming ship;

(iii) mass of the rammed ship
(iv) mass of the ramming ship
(v) speed of the rammed ship
(vi) speed of the ramming ship
} at time of collision

(vii) relative course angle between rammed and ramming ship;

(viii) location of damage relative to the ship's length.

From the point of view of the rammed ship only item 1 is determined; all other items are random. An investigation of the damage length of ships with different numbers of decks has shown that there is no significant influence. This does not prove that there is no influence. It is,however, valid to conclude that the influence of structural characteristics is rather small. It therefore seems justified to neglect this influence.

The mass of the rammed ship depends on its size and its loading condition. The influence of the latter is small, especially for passenger ships. For the matter of simplicity it has been neglected. To account for the size of the rammed ship, damage length has been related to the ship length and damage penetration to the ship breadth.

The following will show that the damage length does not depend significantly on the place in which it occurs in the ship's length. From this it is concluded that the damage extent does not depend on the location of the damage except at the ship ends where damage length is bounded according to the definition of damage location as the centre of the damage.

Some comments on the mass of the ramming ship are given below.

(c) Distribution of damage length.

Preliminary investigations have led to the conclusion that the distribution of the ratio damage length to ship length y/L is approximately independent of the ship length. A proof will be given below. As a consequence y/L can be taken as independent from L.

From theoretical considerations (using the central limit theorem) it follows that $y/_L + \varepsilon_y$ (where ε_y is a constant) is approximately log-normal distributed. This is proved by Figures 4.6 and 4.7, which show good agreement between the log-normal distribution function and distribution density on the one hand and the corresponding results of the damage statistics.

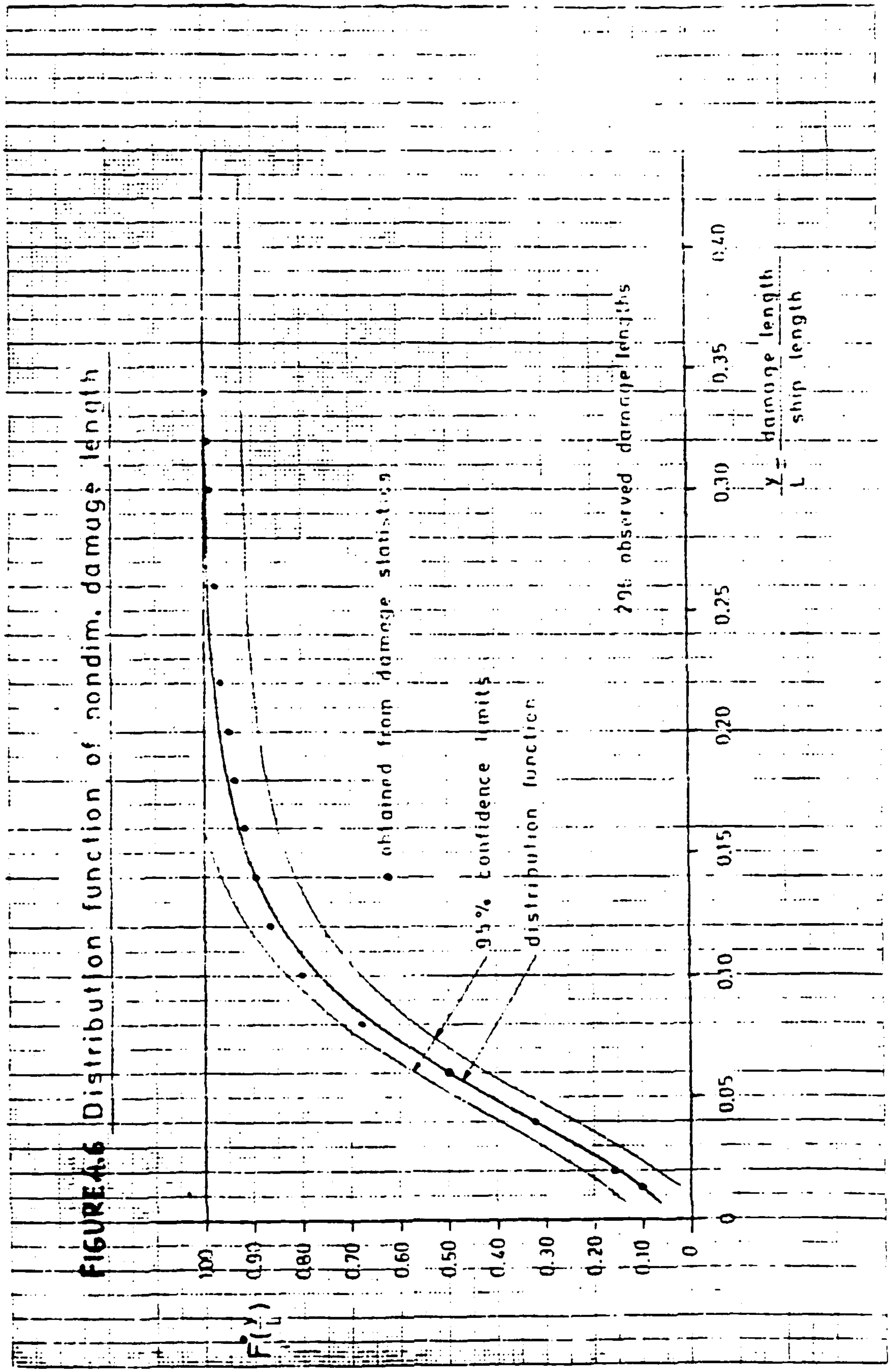


FIGURE 4.6 Distribution function of nondim. damage length

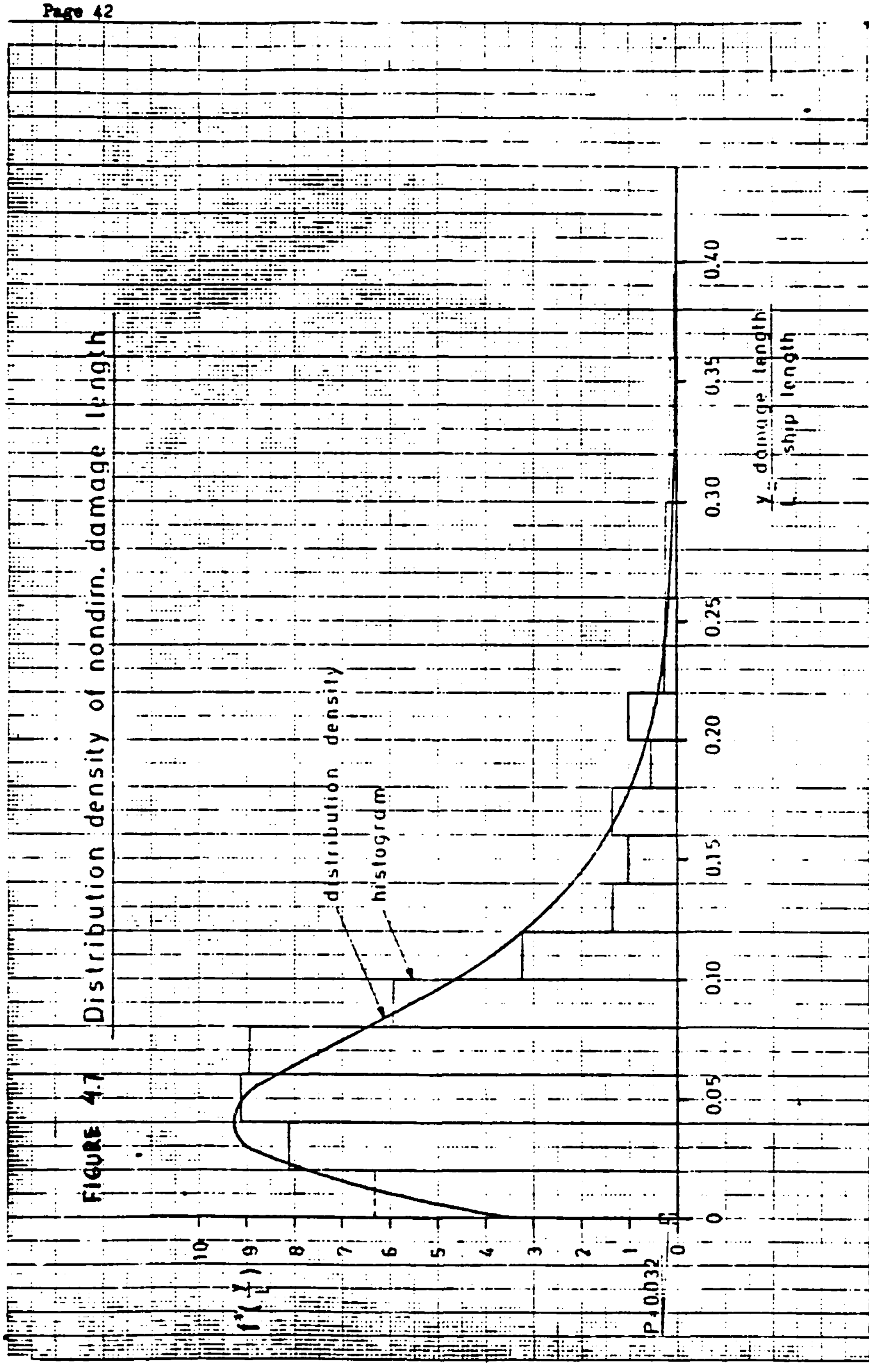


FIGURE 4.7 Distribution density of nondim. damage length

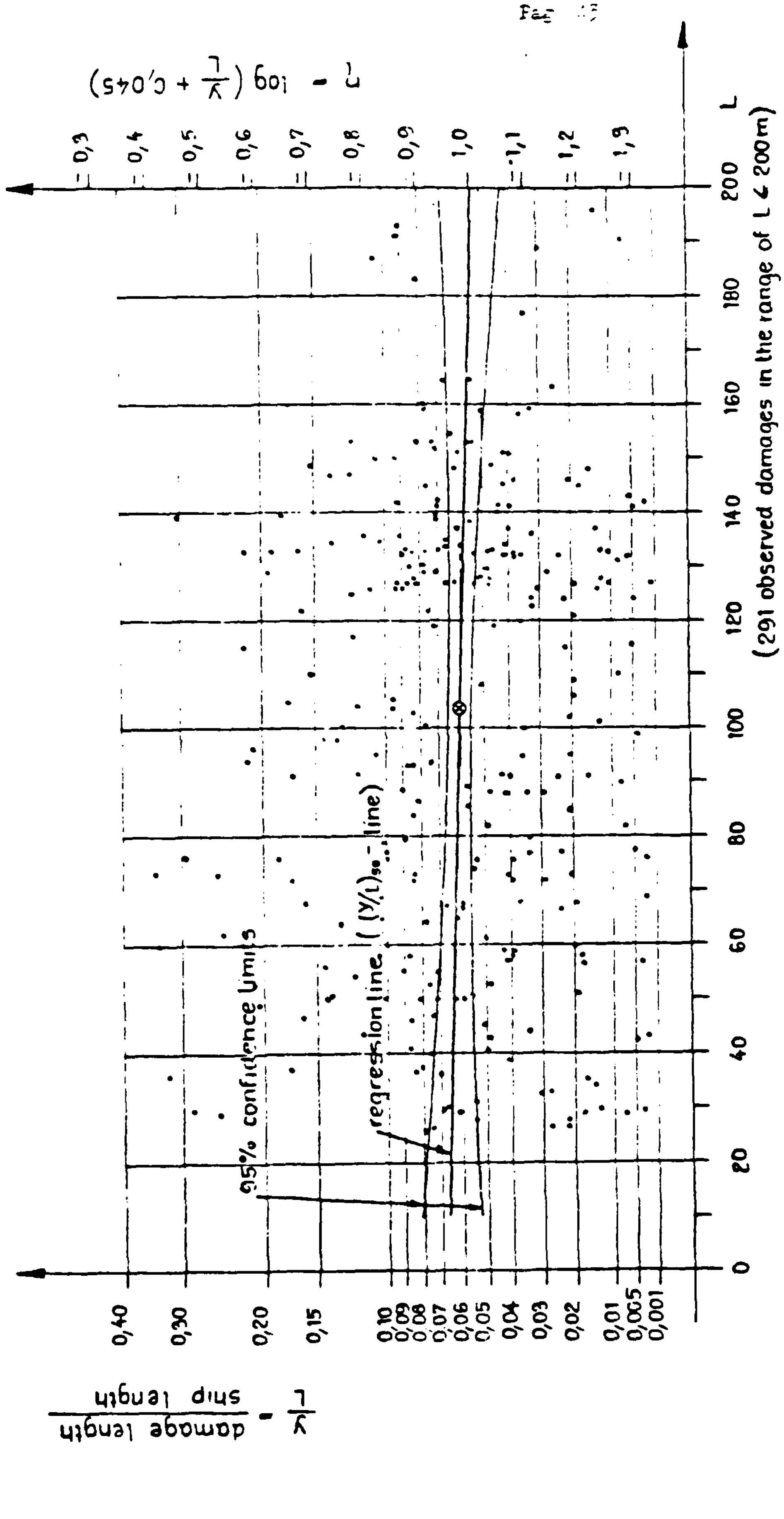


Figure 4.8 Regression of nondim. damage length on ship length.

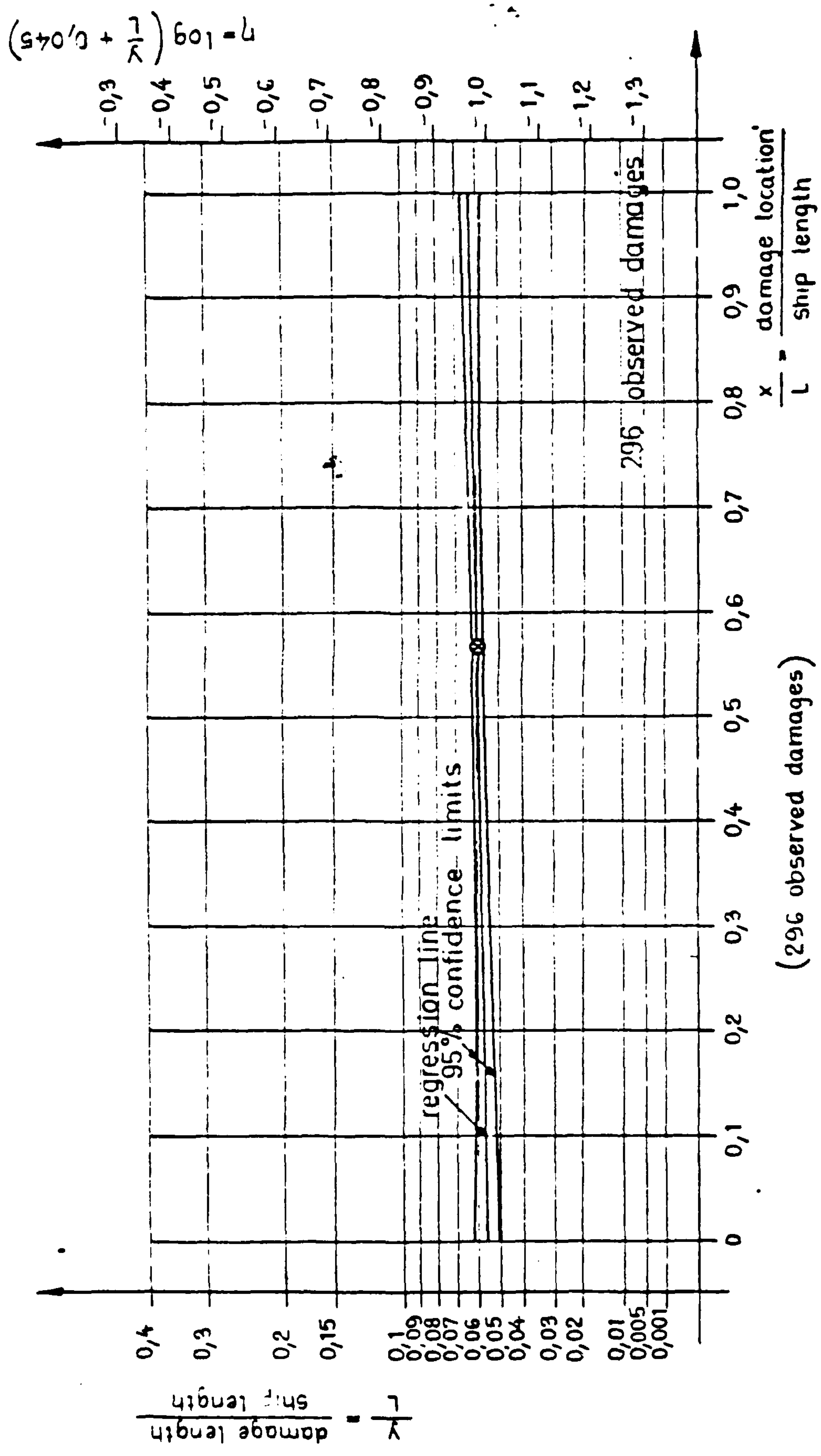


Figure 4.9 Regression of nondim. damage length on nondim. damage location

Figure 4.8 shows the regression of y/L on L for $L \leqslant 200$ m (five damages belong to ships with $L > 200$ m). The regression line has a small negative slope which proved to be insignificant. That means that it may be caused by samples taken at random. There might be a small dependence of y/L on the ship length, but it is so small that it cannot be derived from the given sample. It is therefore certainly no grave error to assume y/L to be independent of ship size for $L \leqslant 200$ m.

An explanation of this independence might be that small vessels are more likely to meet mainly small vessels and large vessels are more likely to meet mainly large vessels. However, this reasoning cannot be extended for very large vessels because of the small total number of such ships. Because of the very few damage cases concerning ships with $L > 200$ m nothing can be said about the damage distribution of such ships. It seems reasonable to assume as an approximation for ships with $L > 200$ m that the median of the damage length is constant and equal to the median for $L = 200$ m. The latter equals $200 \cdot (y/L)_{50}$, where $(y/L)_{50}$ is the median of the non-dimensional damage length for ships with $L = 200$ m.

The regression of the non-dimensional damage length y/L on the non-dimensional damage location is shown in Figure 4.9. It shows that there is no significant difference between the damage distributions in the forward and aft half of the ship, but simple geometric reasoning indicates that the damage length at the ends of the ship - forward as well as aft - is limited to smaller values than in the central part of the ship. Therefore the log-normal distribution found for all values of $y/_L$ - independent of damage location - is the marginal distribution. The corresponding conditional distribution of y/L on the condition that the damage location is given does not need to be considered as for the practical application an approximation will be used, which allows establishment of a very simple relationship between the conditional and marginal damage length distribution.

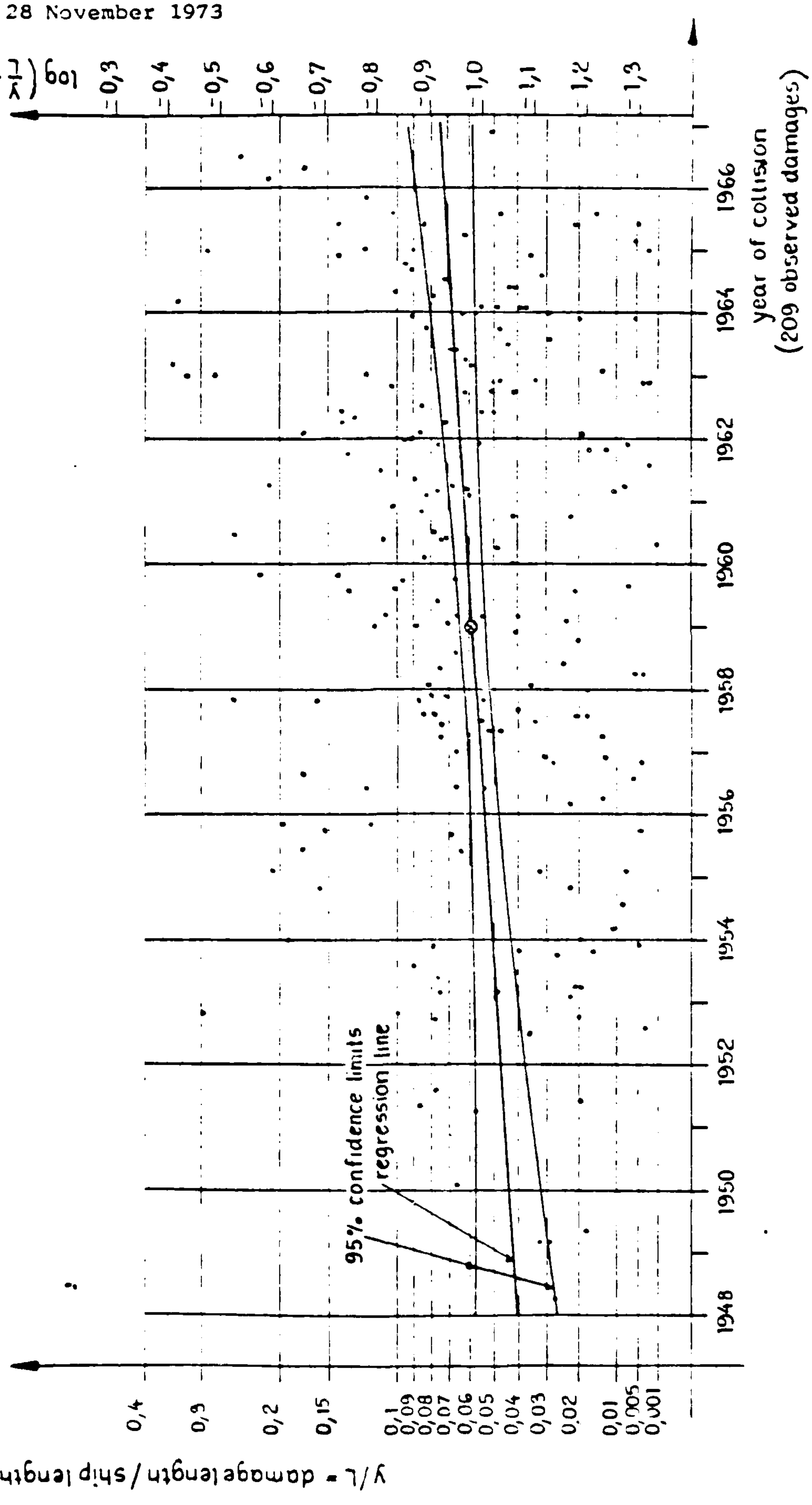


Figure 4.10 Regression of nondim damage length on year of collision

(d) Dependence of damage length on year of collision.

Increasing speed and size of ships during recent years suggests that the average size of damage in cases of collision also is growing. In order to investigate this presumption a regression analysis of the logarithm of the non-dimensional damage length on the year of collision has been made. The result is shown in Figure 4.10. This figure shows a significant positive slope of the regression line, which proves that, on average, the damage length increases with time.

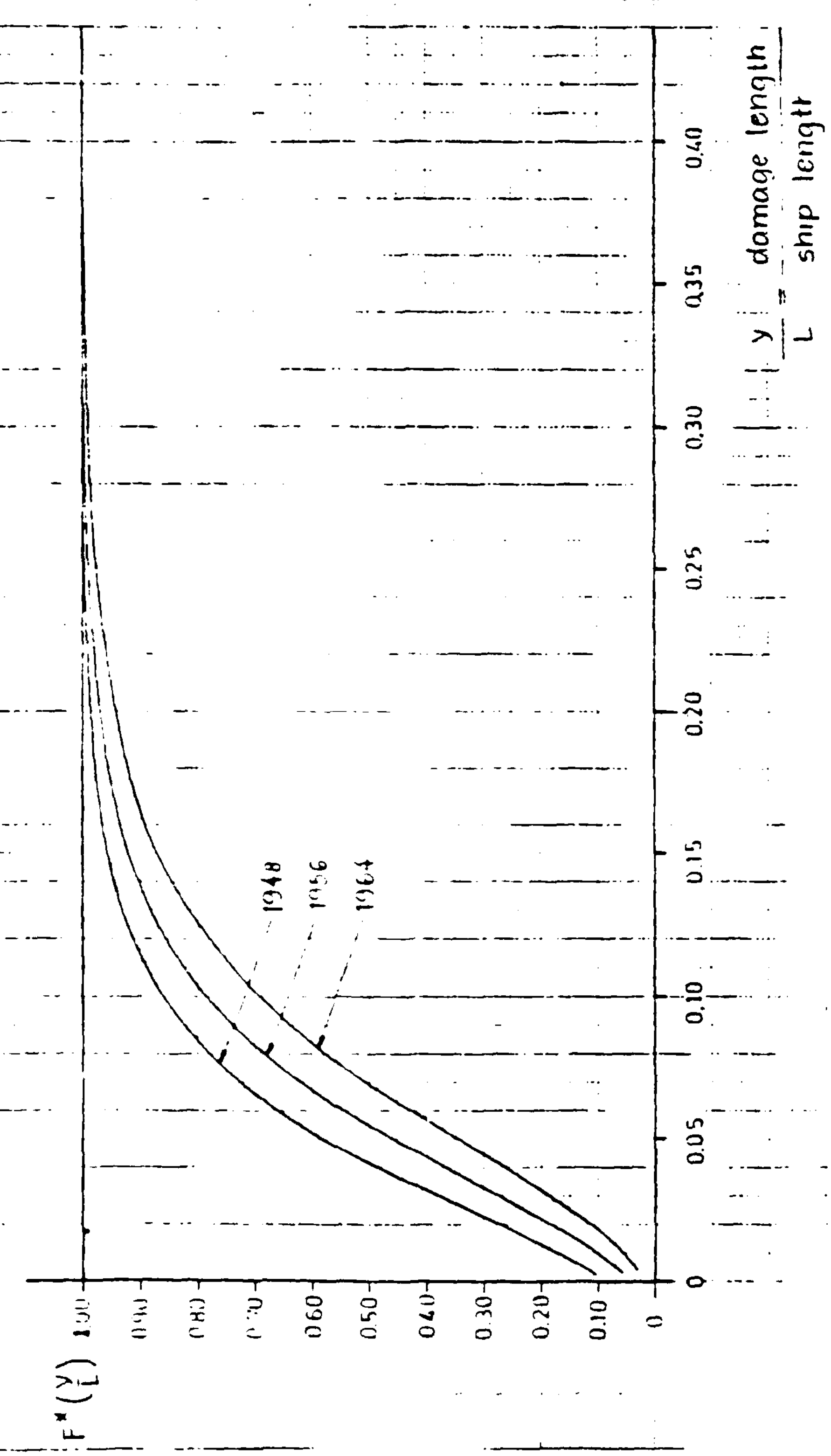
It therefore seems wise not to use the distribution which results from all damage data independent of the year of collision. Assuming that the variance about the regression line is constant it is possible to derive from the regression analysis the distribution function of the non-dimensional damage length for any arbitrarily chosen year; such a function is determined by the mean (which is given by the regression line) and the variance about the regression line of the logarithm of $y/L + \varepsilon_y$. Some samples are given in Figures 4.11 and 4.12.

(e) Distribution of damage penetration.

Similar considerations as in the case of the damage length lead to the conclusion that $z/B + \varepsilon_z$ is approximately log-normal distributed and does not depend on the ship size, which in this connexion is represented by the breadth B of the ship. Figures 4.13 and 4.14 show the good agreement between the log-normal distribution and the corresponding values obtained from the damage statistic. Figure 4.15 proves that there is in fact no significant dependence of z/B on B.

As to be expected, there is a strong correlation between z/B and y/L. Figures 4.16 and 4.17 show that z/B increases in the average with increasing y/L. The joint distribution of the logarithm of $(y/L + \varepsilon_y)$ and $(z/B + \varepsilon_z)$ is a bivariate normal distribution. From that distribution the conditional distribution of z/B on the condition that the damage length assumes certain values y/L can be derived.

Figure 4.11 Distribution function of nondim. damage length for resp. year of collision



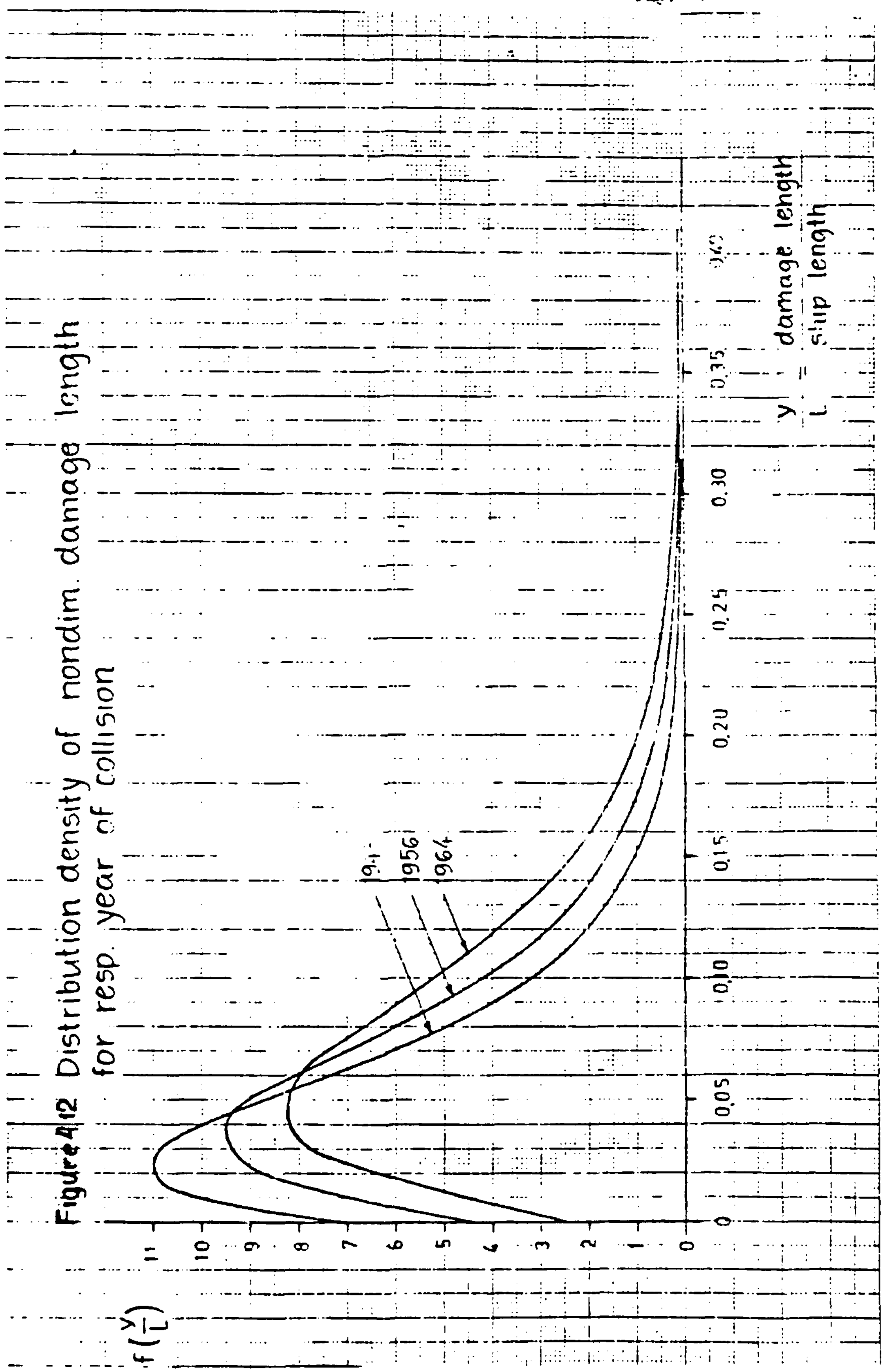
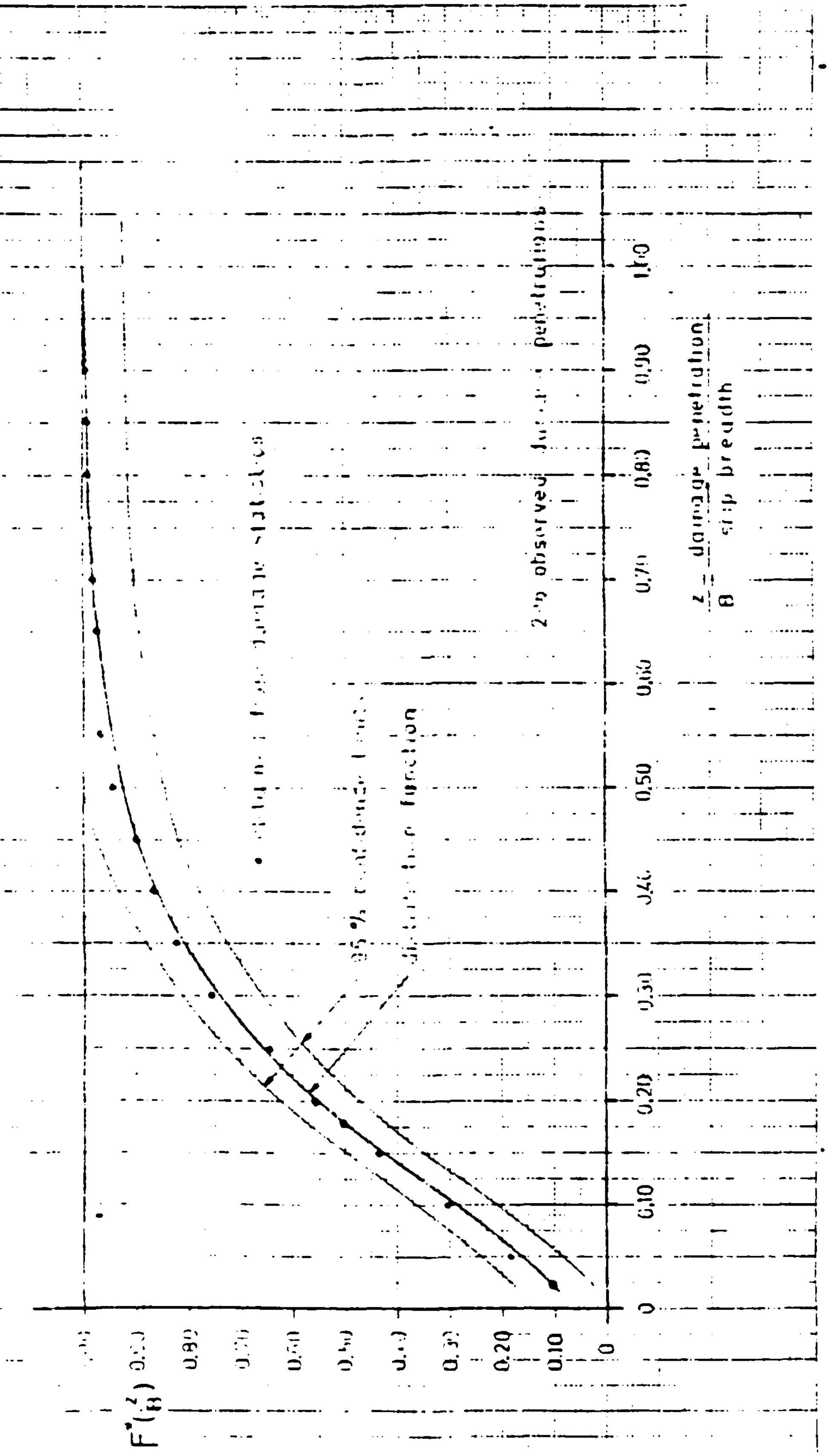


Figure A12 Distribution density of nondim. damage length for resp. year of collision

Figure 4.13 Distribution function of nondim. damage penetration



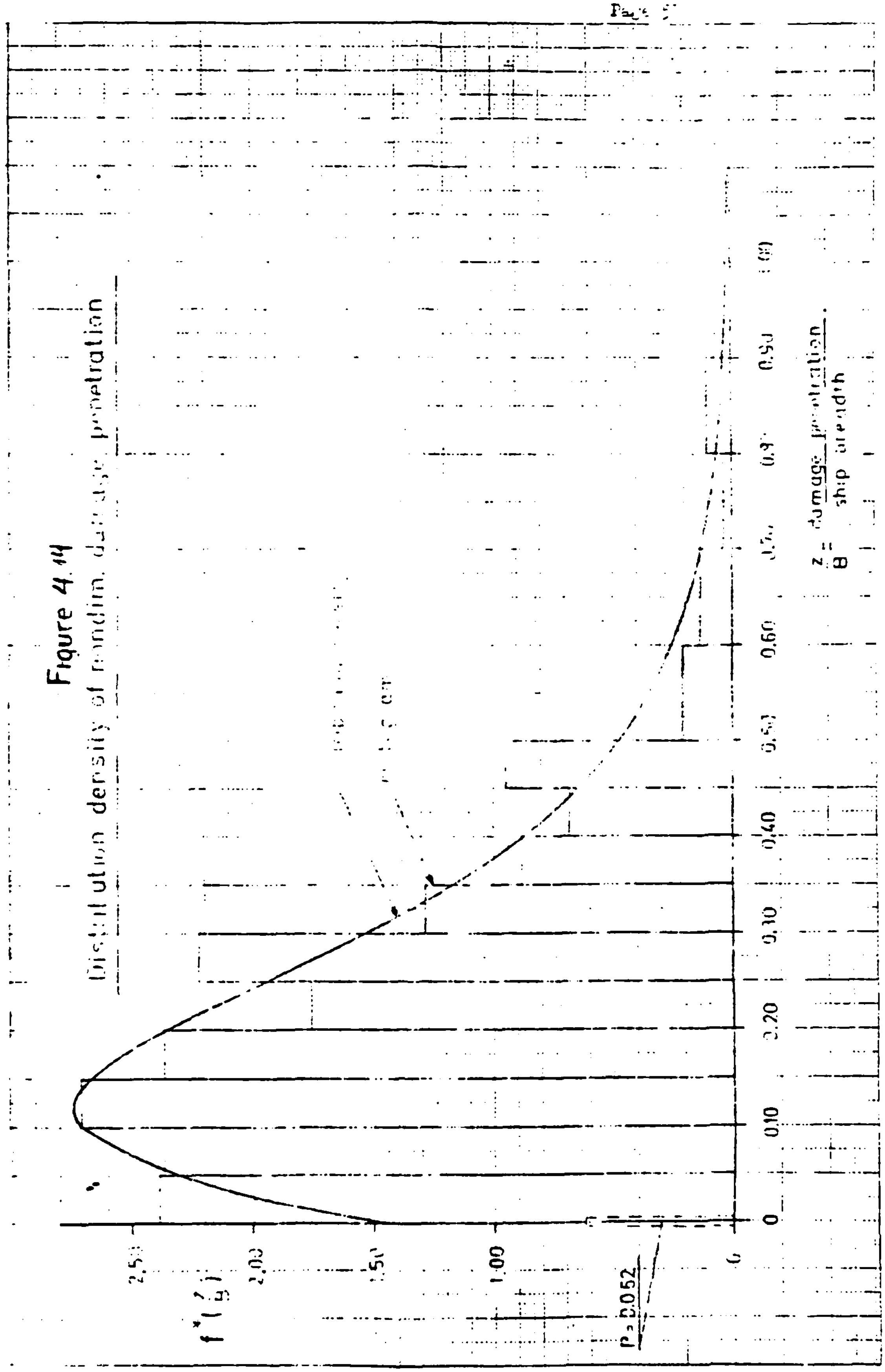
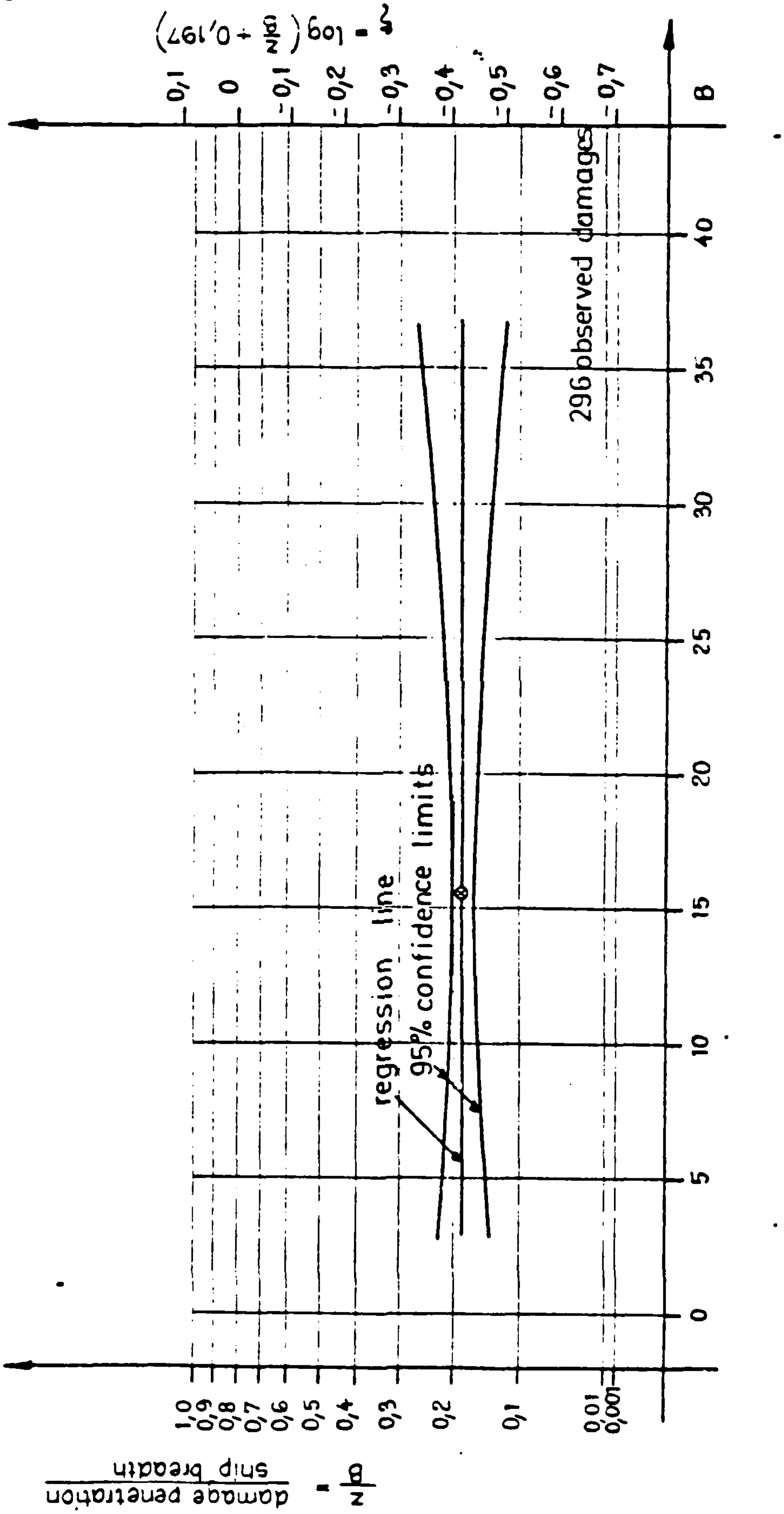


Figure 4.14
Distribution density of random damage penetration

Figure 4.15 Regression of nondim. damage penetration on ship breadth.



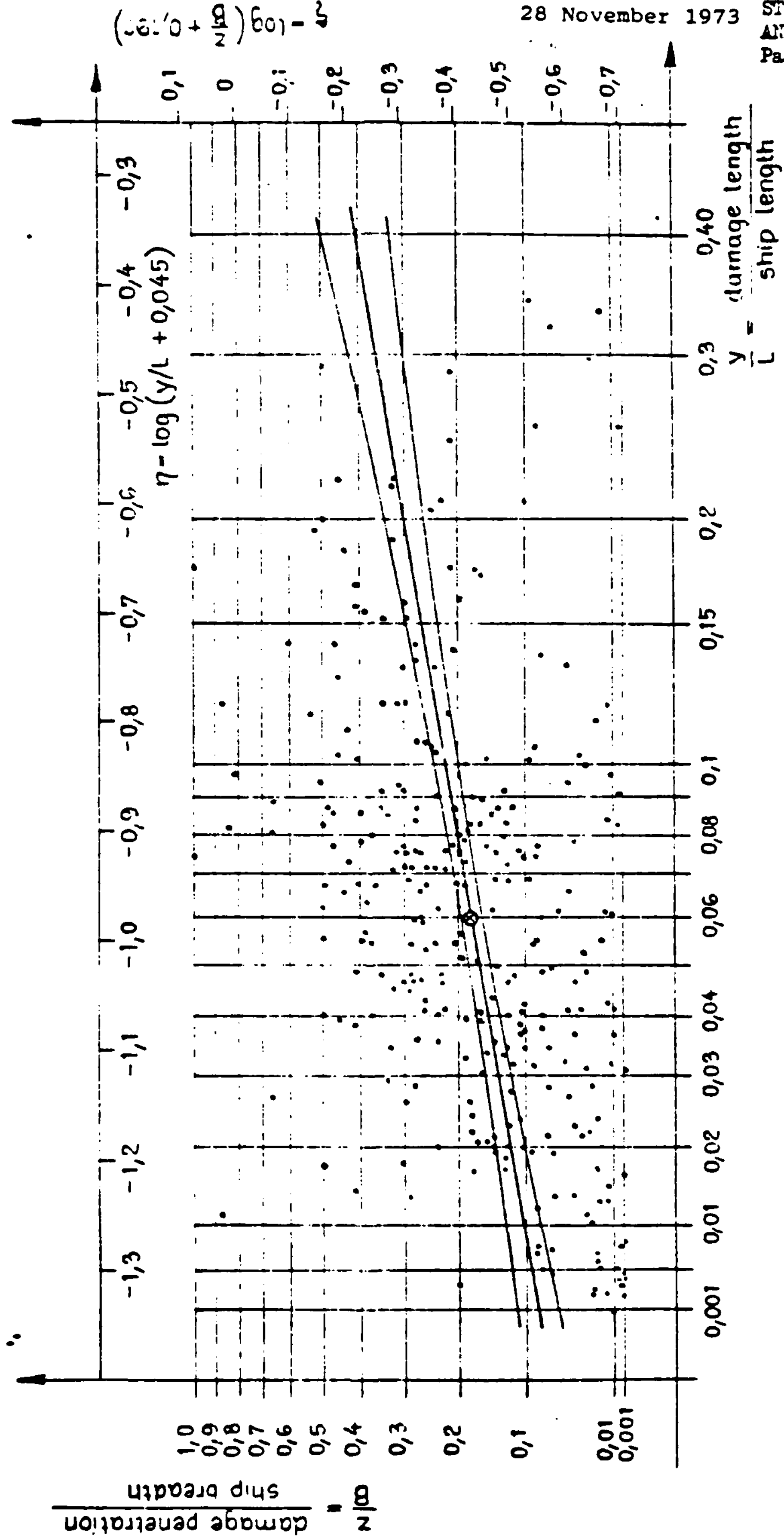
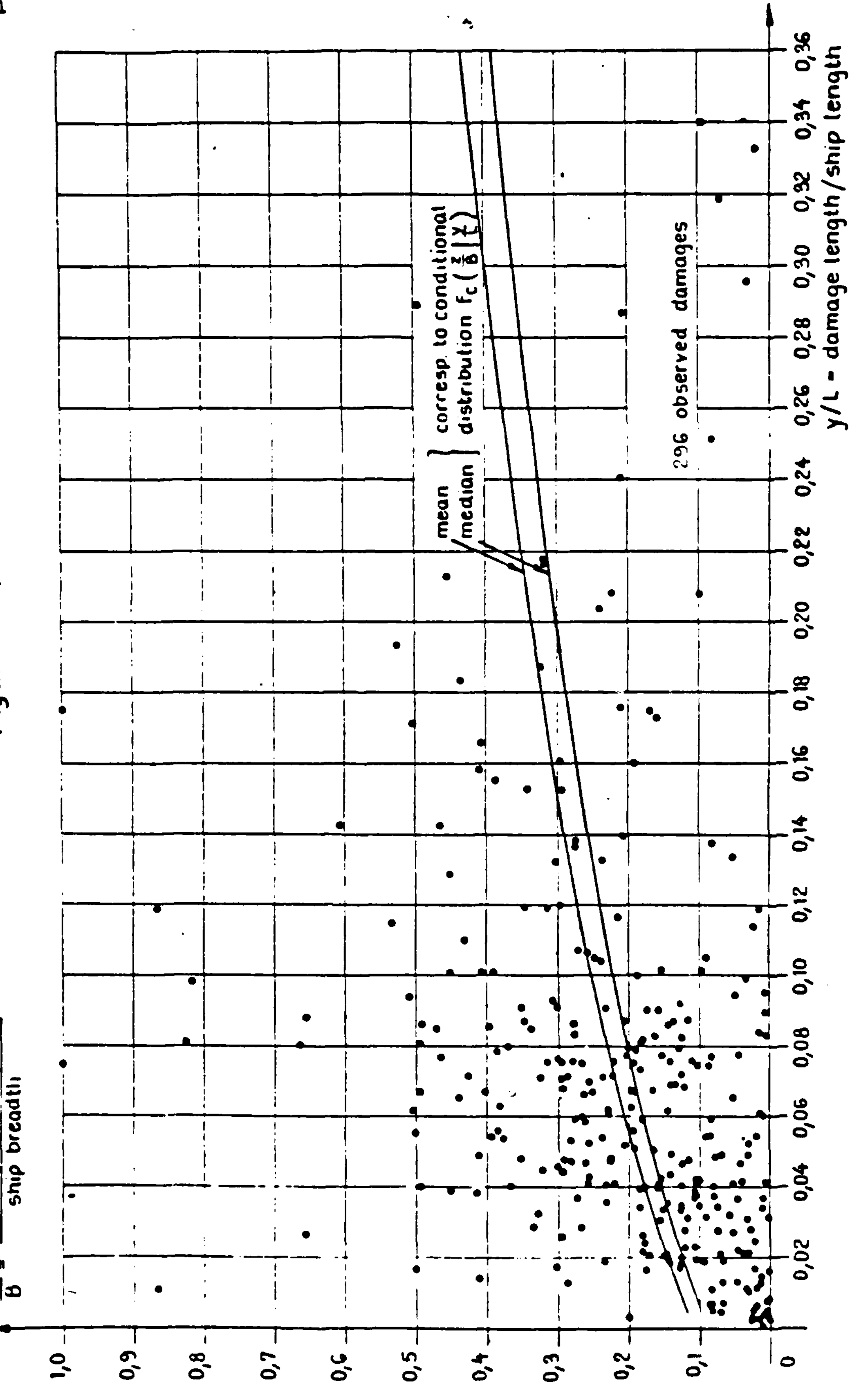

η - log(y/L + 0,045)
y/L = damage length / ship length
z/B = damage penetration / ship breadth

Figure 4.16

Figure 4.17


$\frac{z}{B}$ = $\frac{\text{damage penetration}}{\text{ship breadth}}$
mean
median
corresp. to conditional distribution $f_c\left(\frac{z}{B}\middle|\frac{y}{L}\right)$
296 observed damages
y/L - damage length/ship length
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0,02
0,04
0,06
0,08
0,10
0,12
0,14
0,16
0,18
0,20
0,22
0,24
0,26
0,28
0,30
0,32
0,34
0,36

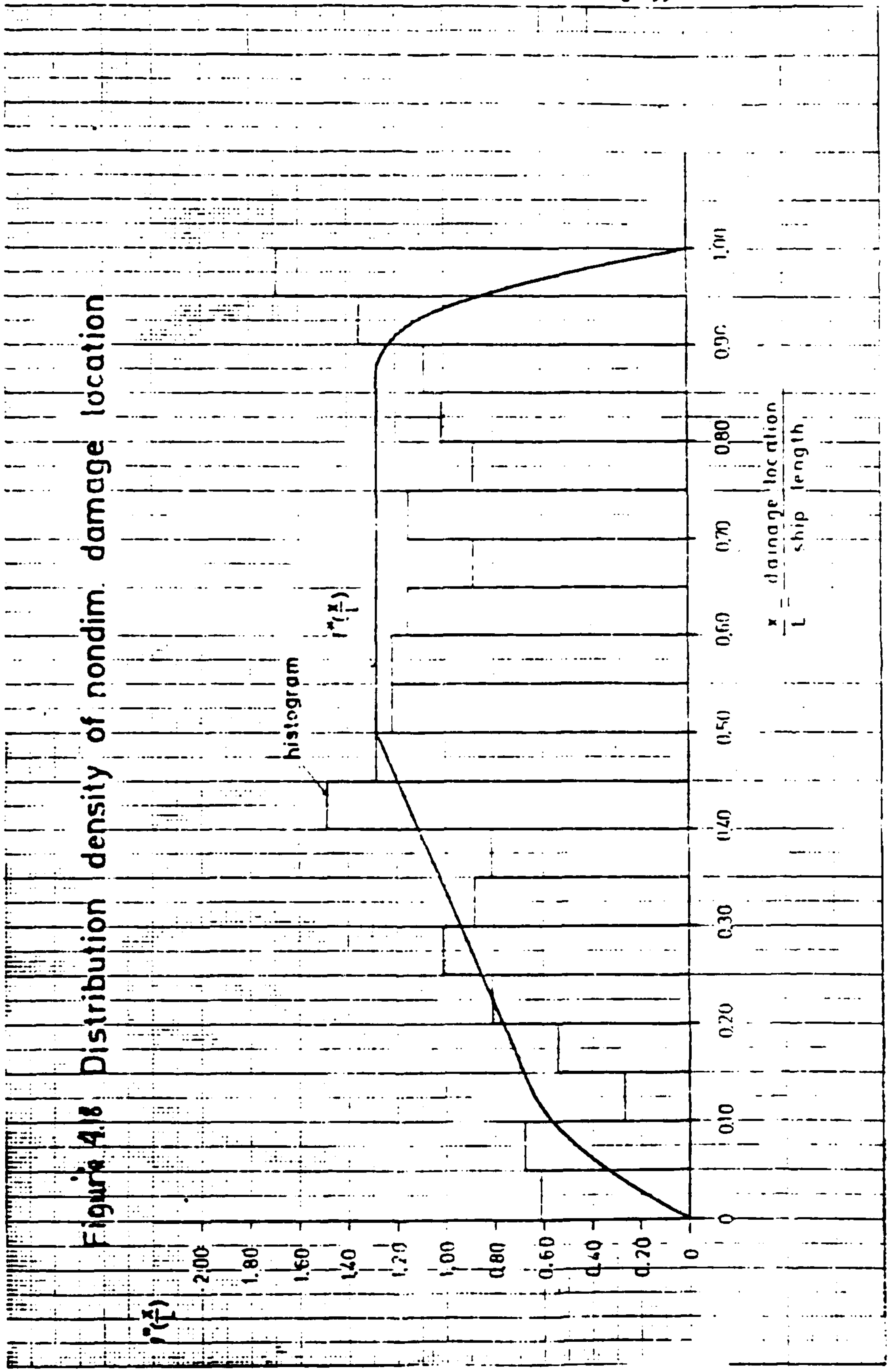


Figure 4.18 Distribution density of nondim. damage location

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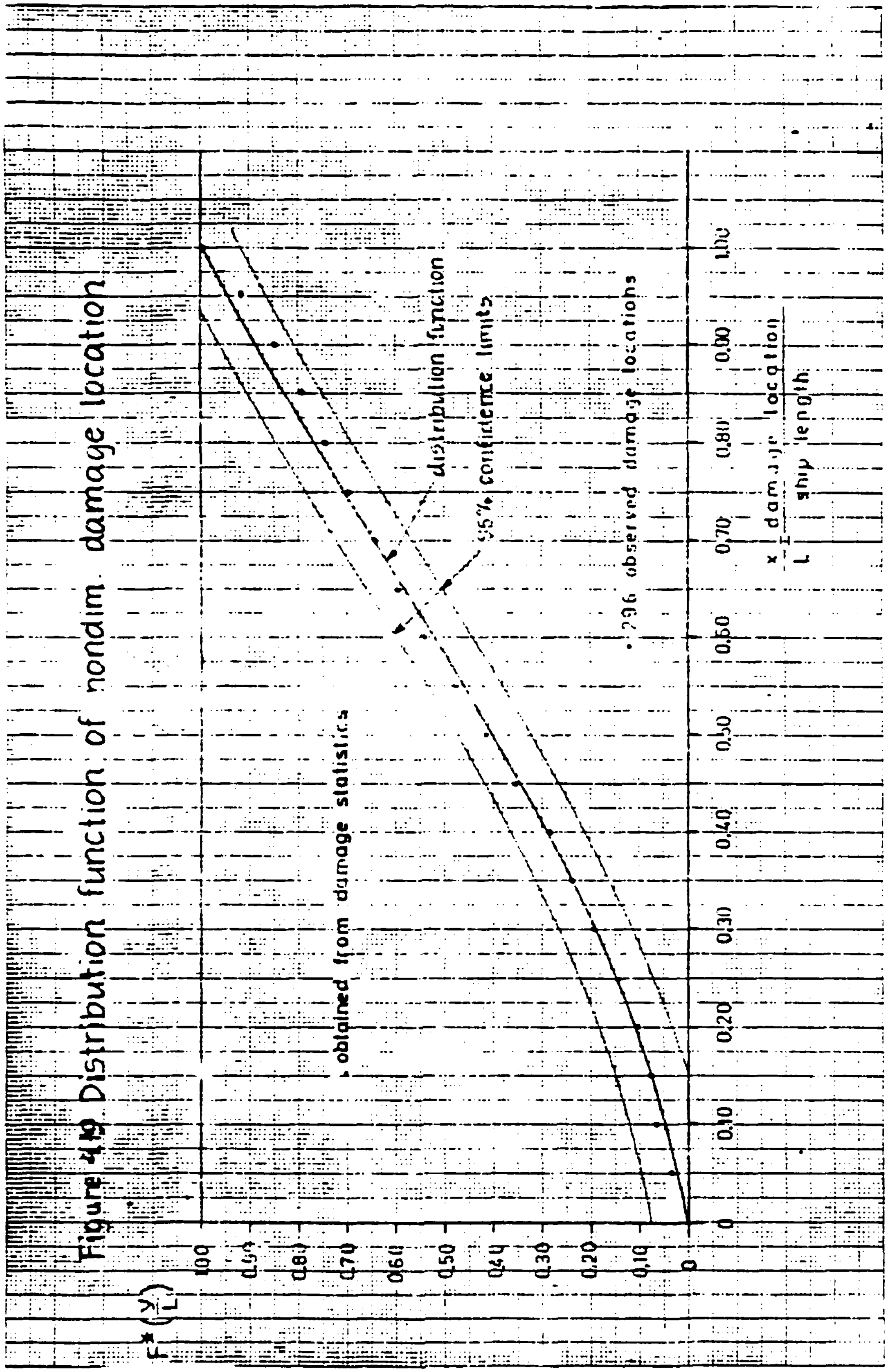


Figure 4.19 Distribution function of nondim. damage location

(f) Distribution of damage location

Inspection of the histogram (Figure 4.18) of the non-dimensional damage location shows that damages in the forward half of the ship are more frequent than in the aft part. No explanation can be offered for the peaks of the histogram at about $x/L = 0.45$ and $x/L = 0.95$, except that they are random because of the limited sample.

Because the damage location is defined as distance from the aft terminal of L to the centre of the damage it always has a distance of $y/_2L$ from the ends of the ship. Starting with a simple assumption for the conditional distribution of x/L on the condition that y/L assumes certain values, the marginal distribution density which is shown as curve in Figure 4.18 has been derived. The corresponding distribution function is given in Figure 4.19.

4. Determination of the Probability that a Damaged Ship will not Capsize or Sink

(a) Criterion for capsizing and sinking.

It is not possible at the present state of knowledge to determine with any degree of accuracy criteria for capsizing of ships in waves. However, it is possible to get a simplified relationship which takes into account only certain parameters and disregards others.

In order to establish a relationship between relevant factors and critical wave height at which a ship capsizes, model tests conducted separately in the United Kingdom and the United States of America were analyzed.

In both of these set of tests it was noted that for any given sea state and freeboard the critical range of GM within which capsizing or survival was uncertain was quite narrow Consequently it was considered justifiable to treat the relationship as determinate even though some degree of randomness may be present, especially in natural sea conditions.

From the results of the model tests it was decided to use GM and effective freeboard rather than righting arm. Observations in the model tests showed that in some cases there could be ambiguity as to the effectiveness

of the righting arms dependent upon the direction of heel and upon structural arrangements. The model tests further showed that the minimum righting arm required for survival relative to waves varies in a complex manner with freeboard.

The results of the model tests showing the relationship between GM, significant wave height and freeboard are given in Figure 4.20.

Supplemental model experiments showed that for any given sea state the GM necessary, in association with any given freeboard, is approximately proportional to the ship's breadth.

The Figure shows that GM and freeboard alone are not fully sufficient to determine the critical wave height. Nevertheless the critical wave height may be expressed as a function of freeboard, GM and breadth:

$$h_{1/3}\text{ critical} = f\left(\frac{GM_e\ F_e}{B_2}\right)$$

where: F_e is the effective freeboard after damage including an allowance both for the virtual increase of freeboard due to erections or sheer and for a decrease of freeboard due to heel;

GM_e is the effective metacentric height flooded; and

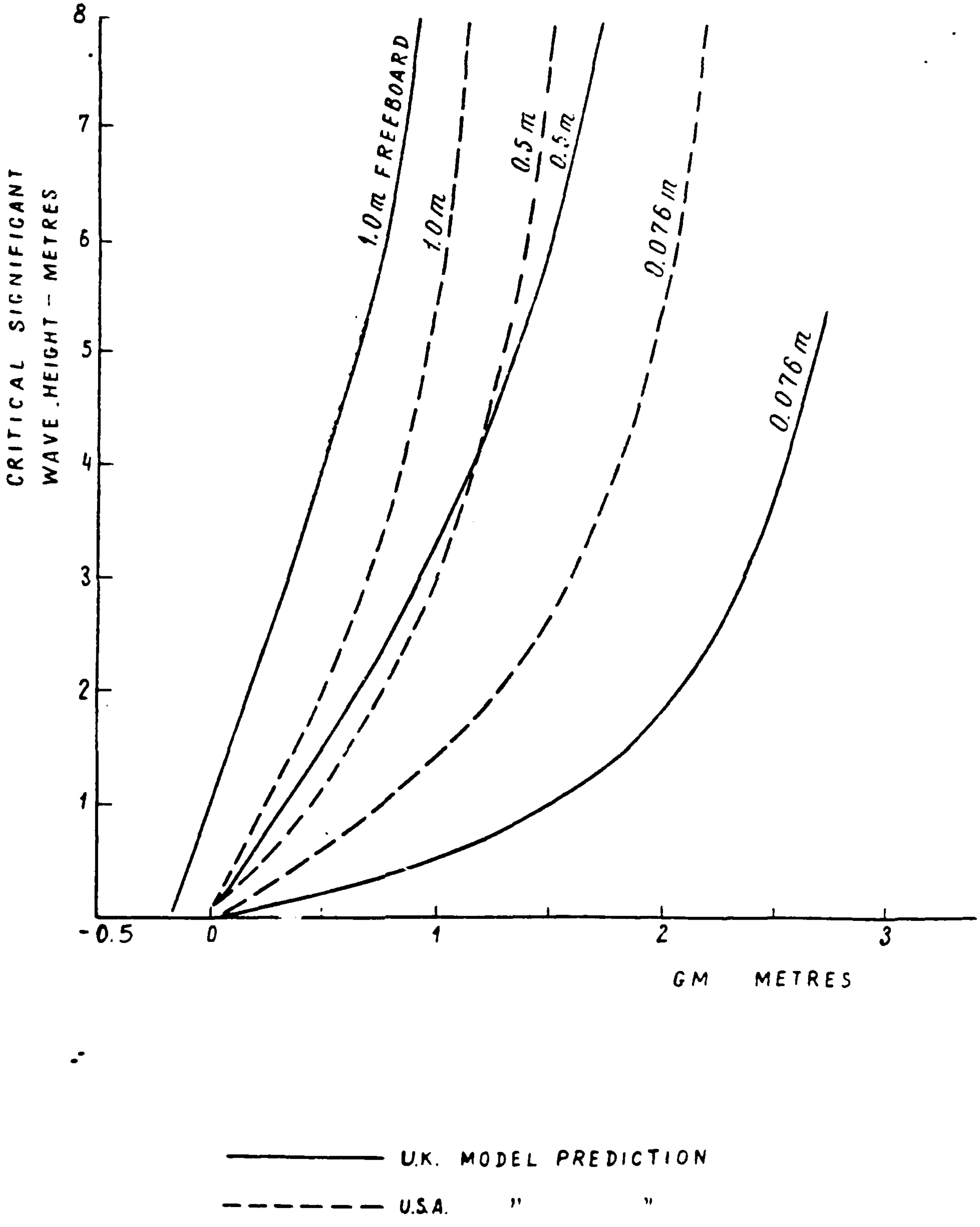
B_2 is the extreme moulded breadth at midlength of the bulkhead deck.

Requiring that the deck of the undamaged part of the ship is not submerged is considered a reasonable criterion that the ship will not sink due to lack of buoyancy.

(b) Wave height distribution

From the sea condition reports of collided ships contained in IMCO Casualty data, the distribution of wave heights has been derived. Figure 4.21 shows this distribution. It may be noted that this distribution of wave heights shows very low wave heights associated with apprec able values of probability. This is because calms were reported in many cases. It is

Figure 4.20 - Mean of Windward and Leeward Results



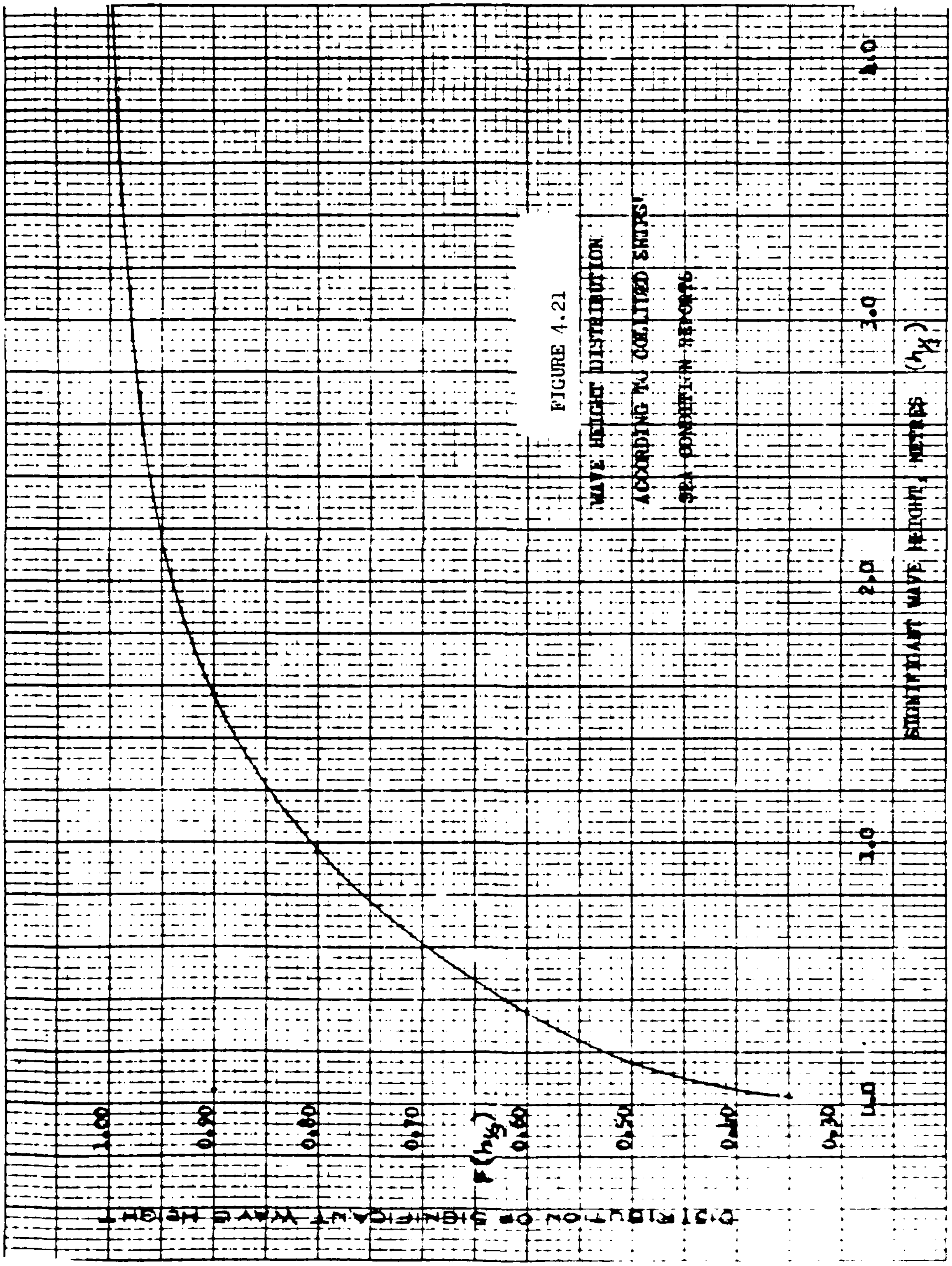


FIGURE 4.21
WAVE HEIGHT DISTRIBUTION
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
1.0
2.0
3.0
4.0

possible, however, that small waves or swell may actually have been present and therefore that more accurate information would have resulted in somewhat greater wave heights at those probability levels. Also, independent of sea conditions, ships are subject to other sources of heeling moments such as unsymmetrical distribution of persons, tankage, etc.

Therefore a slight modification of the distribution appeared to be in order.

(c) Draught and permeability distribution.

As background information, cargo loading data for 16 ships involving a total of 569 departures plus arrivals was analyzed in order to find the distribution of draught and permeability.

Examination of these data indicates that the average of the cargo space permeabilities varied with draught in a logical manner.

For ships having a small range of operating draughts (due appreciably or principally to variations in tankage), the likelihood is high that cargo spaces may be only slightly occupied or empty even when the draught of the ship is near d_s. On the other hand, for ships having a greater range of operating draughts there is greater likelihood that some of this draught range will be due to variations in cargo and therefore that cargo spaces may be occupied by some cargo at any draught. At the same time, for any given ship, the possibility increases that the cargo spaces may be only partially filled or empty, as the operating draught decreases.

For the purposes of simplicity only the marginal distribution of the draught is used. The variation of permeability is taken into account by using the average dependency of permeability on draught.

Taken as a whole it appeared that the draught distribution density may be assumed triangular with its maximum value at $d_o + \frac{2}{3}(d_s - d_o)$, where d_o is the lightest service operating draught and d_s is the subdivision draught, see Figure 2.9. The average relationship between permeability and draught

is given in new Regulation 4(b). Figure 4.22 shows, for two of the sample ships, how their permeabilities compare with the permeabilities given by the formula.

(d) Determination of the probability of not capsizing or sinking.

The probability that a ship with a given GM and freeboard will not capsize is equal to the probability that the critical wave height related to those parameters is not exceeded. Therefore the probability s_i that a ship will not capsize can be derived from the wave height distribution. A simple approximation of this probability is:

$$s_i = k\left[\frac{F_e \; GM_e}{B_2}\right]^{\frac{1}{2}} \quad \text{but not more than 1.0}$$

In the interest of comparing the results of this formula with the model experiments, the following information for probabilities near 1.0 and 0.5 is given:

COMPARISON BETWEEN UK/US MODEL TEST AND FORMULA GM'S RELATIVE TO SAFETY (MODEL GM'S ARE THE MEAN OF THE WINDWARD AND LEEWARD RESULTS)						
	U.K. TESTS			U.S. TESTS		
	SHORT VOYAGE VEHICLE FERRY			LONG VOYAGE TYPE SHIP		
	111.0 (L_s)x 16.78 (B_1)x 5.65 (D)			170.0 (L_s)x 23.17 (B_1)x 13.6 (D)		
S_i	F_e (metres)	GM REQUIRED ACCORDING TO:		F_e (metres)	GM REQUIRED ACCORDING TO:	
		MODEL TESTS	FORMULA		MODEL TESTS	FORMULA
0.99	1.190	0.45	0.58	1.330	0.77	0.71
	0.690	1.05	0.99	0.830	1.11	1.14
	0.266	2.45	2.58	0.406	1.72	2.33
0.50	1.190	-0.15	0.19	1.330	0.03	0.18
	0.690	0.05	0.25	0.830	0.08	0.29
	0.266	0.35	0.66	0.406	0.16	0.59

The probability that the ship will sink due to lack of buoyancy is taken into account by assuming $s_i = 0$ in all cases where the deck of the undamaged part of the ship is submerged.

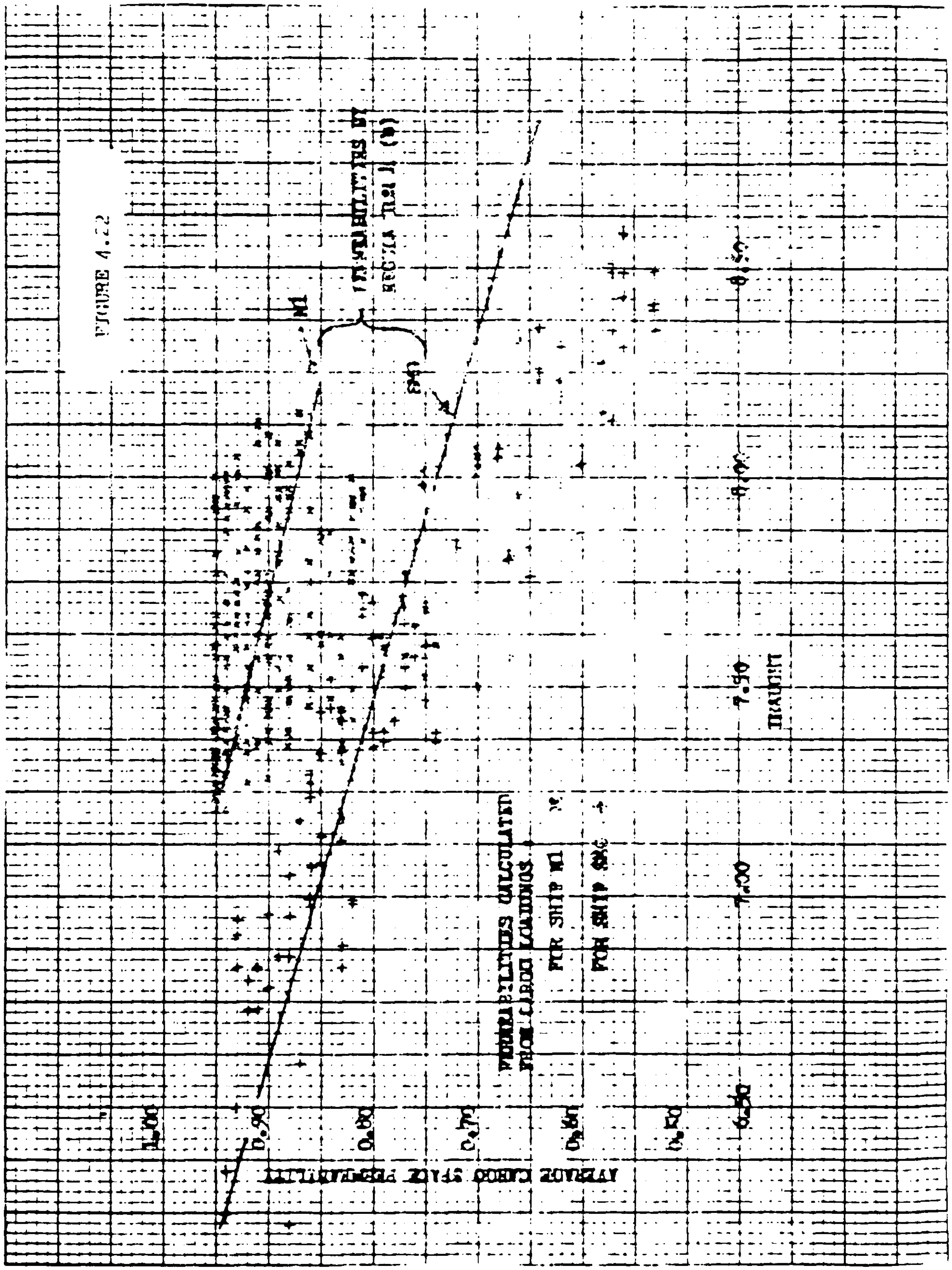

AVERAGE CARGO SPACE PERMEABILITY
DRAUGHT
PERMEABILITIES CALCULATED FROM CARGO LOADINGS
FOR SHIP M1
M1
1.00
0.90
0.80
0.70
0.60
0.50
6.50
7.00
7.50
8.00
8.50

FIGURE 4.22

5. Calculation of the s-value

The formula for s_i gives only the probability at a given draught and GM. It is necessary to obtain the composite probability for all combinations of draught and GM. For purposes of simplicity the random variation of GM in service is neglected and only the required GM as a function of draught is used.

The s-value for the complete range of draughts is obtained by integrating the product of s_i which is a function of draught and the distribution density of draught over the draught range.

APPENDIX I

TRANSVERSE SUBDIVISION

1. Figure 4.A.1 attached hereto shows two compartments named A and B. Compartment A is divided by local subdivision into the spaces A_1 and A_2. For the purpose of calculating the products a p s which contribute to the attained subdivision index the following fictitious compartments and groups of compartments have to be considered:

(1) compartment 1 of length l_1 : p based on l_1
s based on flooding of space A_1

(2) compartment 2 of length l_2 : p based on l_2
s based on flooding of space A_1 only or of A_2 only, or of A_1 and A_2, whichever results in the least s-value

(3) compartment 3 (or B) of length l_3 : p based on l_3
s based on flooding of compartment B

(4) compartments 1 + 2 : p based on l_1 and l_2
s based on flooding of A_1 or of A_1 and A_2, whichever results in the least s-value

(5) compartments 2 + 3 : p based on l_2 and l_3
s based on flooding of A_1 and A_2 and B or of A_1 and B or of A_2 and B, whichever results in the least s-value

(6) compartments 1 + 2 + 3 : p based on l_1, l_2 and l_3
s based on flooding of A_1 and B or of A_1 and A_2 and B, whichever results in the least s-value

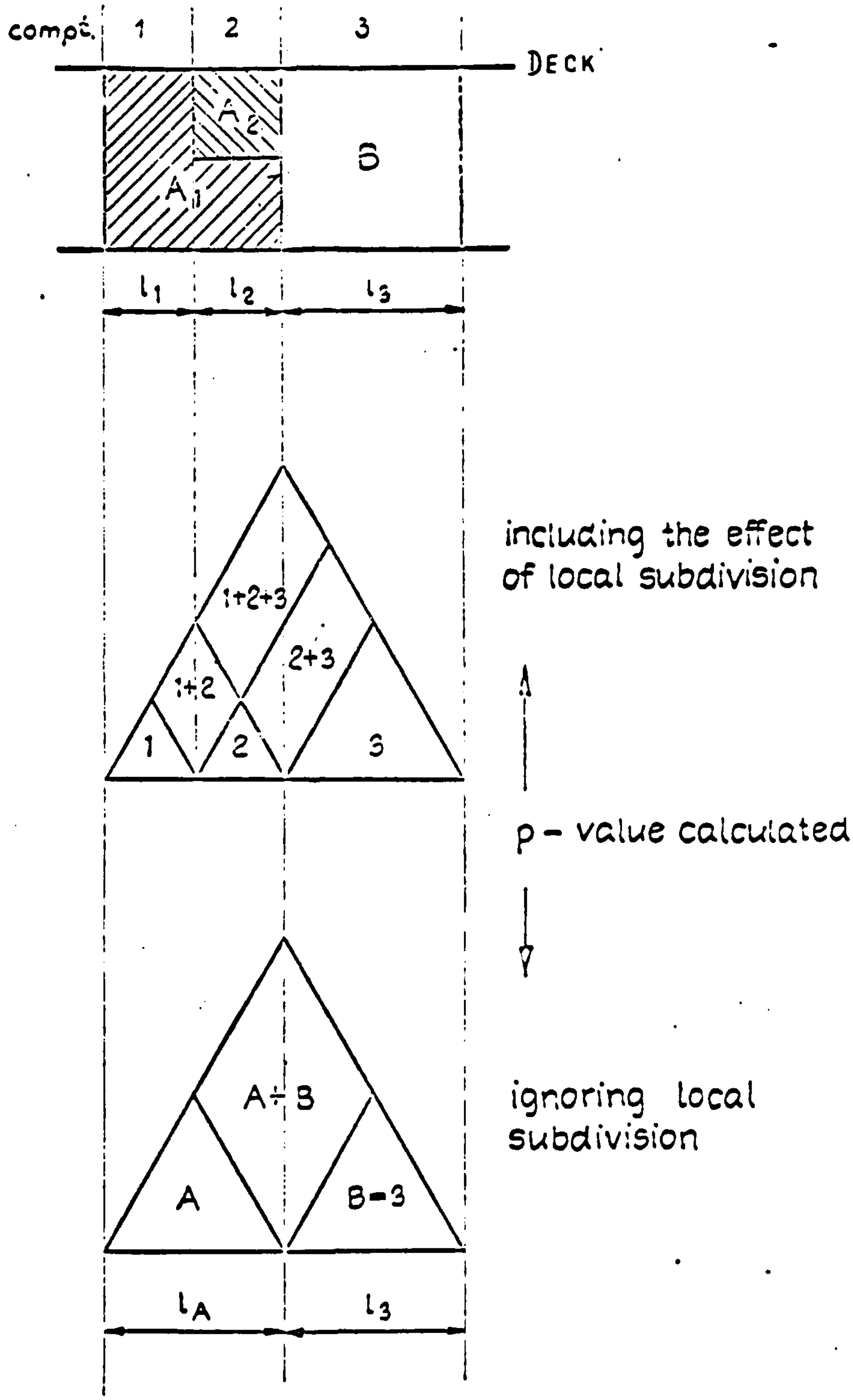

compt.
1
2
3
DECK
A_2
A_1
B
l_1
l_2
l_3
1+2+3
2+3
1+2
1
2
3
including the effect of local subdivision
p - value calculated
A+B
A
B=3
ignoring local subdivision
l_A
l_3

Fig.4.A.1

2. It would be also compatible with the new Regulations to ignore the local subdivision with respect to the calculation of the p-value. In this case the following compartments and group of compartments have to be considered:

(1) compartment A of length $l_A = l_1 + l_2$:	p based on l_A s based on flooding of space A_1 or of space A_2 or of spaces A_1 and A_2, whichever results in the least s-value
(2) compartment B of length l_3:	p based on l_3 s based on flooding of compartment B
(3) compartments A + B:	p based on l_A and l_3 s based on flooding of A_1 and B or of A_2 and B or of A_1 and A_2 and B, whichever results in the least s-value

3. Obviously the approach given in paragraph 1 above will generally lead to a higher (but at least the same) attained subdivision index than the approach of paragraph 2. Also, the error made by neglecting the actual distribution of damage in the vertical direction is much smaller in the first case.

4. Another example of local subdivision is shown in the attached Fig. 4A.2. The following table illustrates how this case can be handled.

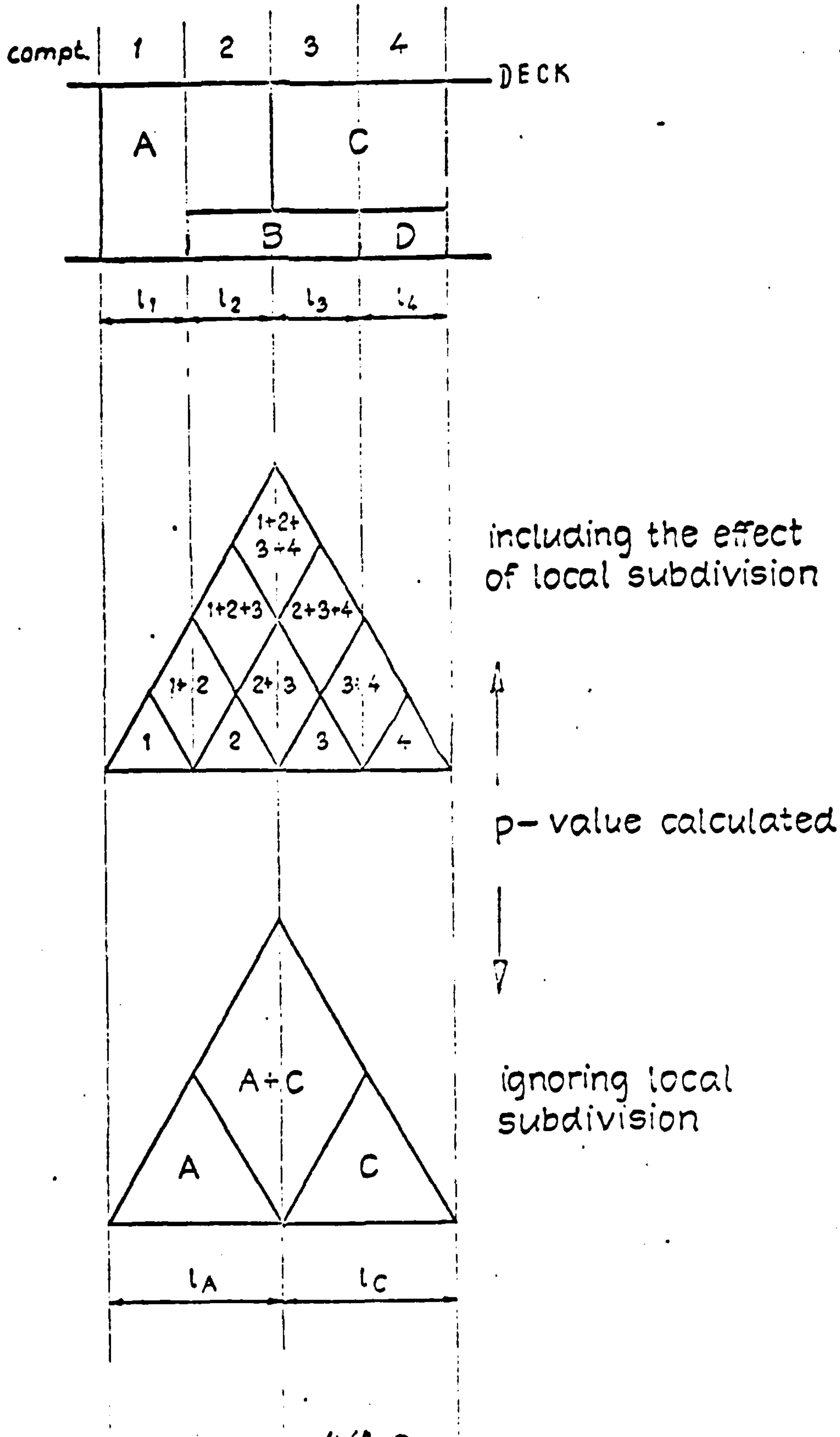

compt.
1
2
3
4
DECK
A
C
B
D
l_1
l_2
l_3
l_4
1+2+
3+4
1+2+3
2+3+4
1+2
2+3
3+4
1
2
3
4
including the effect
of local subdivision
p-value calculated
A+C
A
C
ignoring local
subdivision
l_A
l_C

Fig. 4.A.2

p - value calculated including the effect of local subdivision (see Fig. 4.A.2)

compartment or group of compartments	p based on length(s)	s based on flooding of
1	l_1	space A
2	l_2	space A *or* space B *or* spaces A and B +)
3	l_3	space B *or* space C *or* spaces B and C +)
4	l_4	space C *or* space D *or* spaces C and D +)
1 + 2	l_1, l_2	space A *or* spaces A and B +)
2 + 3	l_2, l_3	space B *or* spaces A and C *or* spaces A and B and C +)
3 + 4	l_3, l_4	space C *or* spaces B and D *or* spaces B and C and D +)
1 + 2 + 3	l_1, l_2, l_3	spaces A and B *or* A and C *or* A and B and C +)
2 + 3 + 4	l_2, l_3, l_4	spaces A and C *or* B and D *or* A and B and C and D +)
1 + 2 + 3 + 4	l_1, l_2, l_3, l_4	spaces A and C *or* A and B and D *or* A and B and C and D +)

+) whichever results in a smaller s-value

p - value calculated ignoring local subdivision (see Fig.4.A.2)

Compartment or group of compartments	p based on length(s)	s based on flooding of
A	$l_A = l_1 + l_2$	space A _or_ space B _or_ spaces A and B +)
C	$l_C = l_3 + l_4$	space C _or_ space B _or_ space D _or_ spaces C and B _or_ spaces B and D _or_ spaces C and D _or_ spaces B and C and D +)
A + C	l_A, l_C	space B _or_ spaces A and C _or_ spaces B and D _or_ spaces A and B and C _or_ spaces A and B and D _or_ spaces A and B and C and D +)

+) whichever results in a smaller s-value

APPENDIX II

I. Combined transverse and longitudinal subdivision

1. Provisions have been included in the new Regulations which permit evaluation and acceptance of ships with combined longitudinal and transverse subdivision. It seems that a full understanding and correct and uniform application of the new provision may be facilitated by some illustrative material. It is based on two different arrangements of combined longitudinal and transverse subdivision as shown in Fig.4.A.3, and 4.A.4, appended hereto.

2. The following nomenclature will be used:

l_1, l_2, l_3..... distances between bulkheads bounding either inboard or wing compartments as shown in Figures 4.A.3 and 4.A.4.

$l_{12} = l_1+l_2$; $l_{23} = l_2+l_3$; $l_{34} = l_3+l_4$ etc.

$l_{1-3} = l_1+l_2+l_3$; $l_{2-4} + l_2+l_3+l_4$ etc.

$l_{2-5} = l_2+l_3+l_4+l_5$; $l_{3-6} = l_3+l_4+l_5+l_6$ etc.

p_1, p_2, p_3 etc. are p calculated by formulae (IV) x)
using l_1, l_2, l_3 etc. as l

p_{12}, p_{23}, p_{34} etc. are p calculated by formulae (IV) x)
using l_{12}, l_{23}, l_{34} etc. as l

---

x) as given in the new Regulations

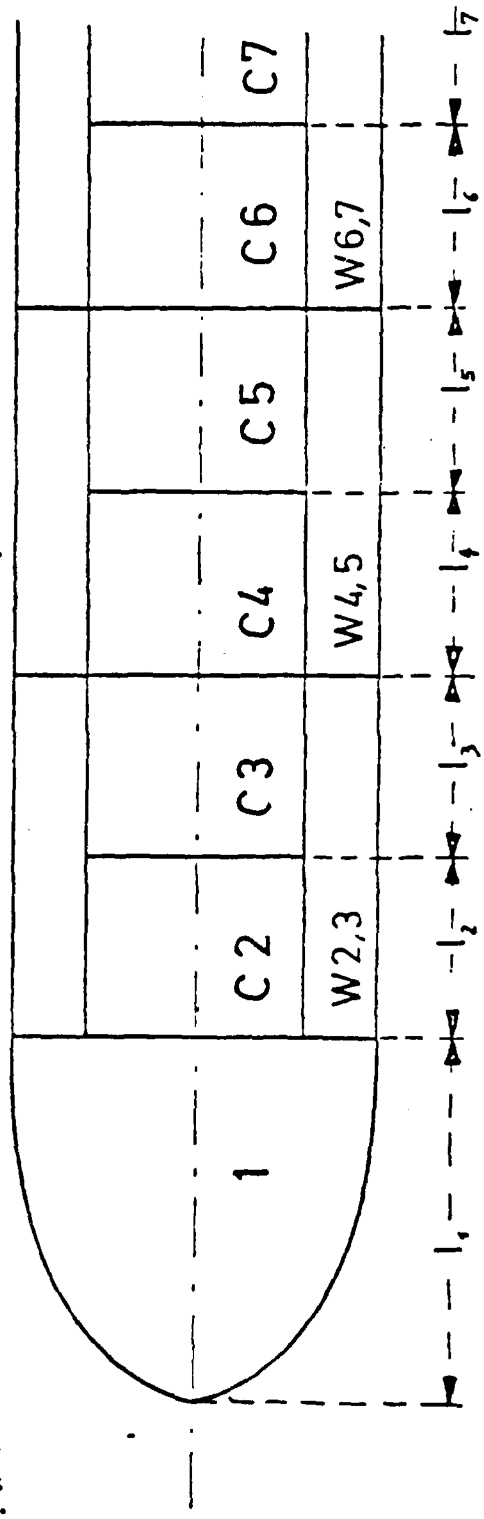


Fig.4A.3

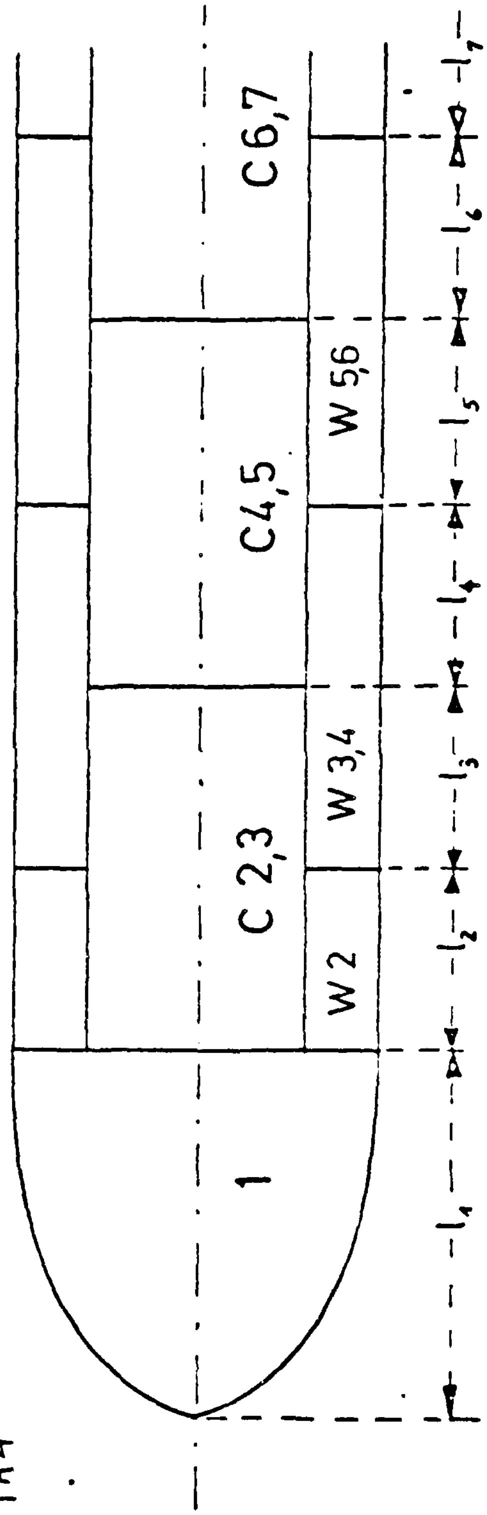


Fig.4A4

p_{1-3}, p_{2-4} etc.	are p calculated by formulae (IV)[x] using l_{1-3}, l_{2-4} etc. as l
p_{2-5}, p_{3-6} etc.	are p calculated by formulae (IV)[x] using l_{2-5}, l_{3-6} etc. as l
r_1, r_2, r_3 etc.	are r calculated by formulae (X)[x] using l_1, l_2, l_3 etc. as l and b as defined in the paragraph following the aforementioned formulae (X)[x]
r_{12}, r_{23}, r_{34} etc.	are r calculated by formulae (X)[x] using l_{12}, l_{23}, l_{34} etc. as l and b as defined in the paragraph following the aforementioned formulae (X)[x]
r_{2-5}, r_{3-6} etc.	are r calculated by formulae (X)[x] using l_{2-5}, l_{3-6} etc. as l and b as defined in the paragraph following the aforementioned formulae (X)[x]

---

x) as given in the new Regulations

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3. Application of Regulation 7 (b) to subdivision arrangement shown in Fig.4.A.3

compartment or group of compartments+)	p-factor	Distances X_1 and X_2 for determination of factor a	
1	$p = p_1$	$X_1 = 0$	$X_2 = l_1$
W 2,3	$p = p_{23}\ \ r_{23}$	$X_1 = l_1$	$X_2 = l_{1-3}$
W 4,5	$p = p_{45} \cdot r_{45}$	$X_1 = l_{1-3}$	$X_2 = l_{1-5}$
1 and W 2,3	$p=p_{1-3} \cdot r_{1-3} - p_1 \cdot r_1 - p_{23} \cdot r_{23}$	$X_1 = 0$	$X_2 = l_{1-3}$
W 2,3 and W 4,5	$p=p_{2-5} \cdot r_{2-5} - p_{23} \cdot r_{23} - p_{45} - r_{45}$	$X_1 = l_1$	$X_2 = l_{1-5}$
1 and W 2,3 and W 4,5	$p=p_{1-5} \cdot r_{1-5} - p_{1-3} \cdot r_{1-3} - p_{2-5} \cdot r_{2-5} + p_{23} \cdot r_{23}$	$X_1 = 0$	$X_2 = l_{1-5}$
W 2,3 and W 4,5 and W 6,7	$p=p_{2-7} \cdot r_{2-7} - p_{2-5} \cdot r_{2-5} - p_{4-7} \cdot r_{4-7} + p_{45} \cdot r_{45}$	$X_1 = l_1$	$X_2 = l_{1-7}$

+) to be considered flooded for s-calculation

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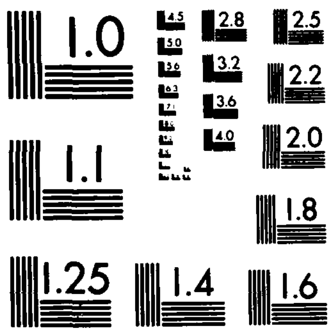

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4. Application of Regulation 7 (c) to subdivision arrangement shown in Fig.4.A.3.

compartment or group of compartments*)	p-factor	Distances X_1 and X_2 for determination of factor a
C 2 and W 2,3	$p = p_2 \cdot (1-r_2)$	$X_1 = l_1$ $X_2 = l_{12}$
C 3 and W 2,3	$p = p_3 \cdot (1-r_3)$	$X_1 = l_{12}$ $X_2 = l_{1-3}$
C 4 and W 4,5	$p = p_4 \cdot (1-r_4)$	$X_1 = l_{1-3}$ $X_2 = l_{1-4}$
1 and C 2 and W 2,3	$p=p_{12}(1-r_{12})-p_1(1-r_1)-p_2(1-r_2)$	$X_1 = 0$ $X_2 = l_{12}$
C 2 and C 3 and W 2,3	$p=p_{23}(1-r_{23})-p_2(1-r_2)-p_3(1-r_3)$	$X_1 = l_1$ $X_2 = l_{1-3}$
C 3 and C 4 and W 2,3 and W 4,5	$p=p_{34}(1-r_{34})-p_3(1-r_3)-p_4(1-r_4)$	$X_1 = l_{12}$ $X_2 = l_{1-4}$
1 and C 2 and C 3 and W 2,3	$p=p_{1-3}(1-r_{1-3})-p_{12}(1-r_{12})-p_{23}(1-r_{23})+p_2(1-r_2)$	$X_1 = 0$ $X_2 = l_{1-3}$
C 2 and C 3 and C 4 and W 2,3 and W 4,5	$p=p_{2-4}(1-r_{2-4})-p_{23}(1-r_{23})-p_{34}(1-r_{34})+p_3(1-r_3)$	$X_1 = l_1$ $X_2 = l_{1-4}$

*) to be considered flooded for s-calculation

5. Application of Regulation 7 (b) to subdivision arrangement shown in Fig.4.A.4.

compartment or group of compartments*)	p-factor	Distances X_1 and X_2 for determination of factor a	
1	$p = p_1$	$X_1 = 0$	$X_2 = l_1$
W 2	$p = p_2 \cdot r_2$	$X_1 = l_1$	$X_2 = l_{12}$
W 3,4	$p = p_{34} \cdot r_{34}$	$X_1 = l_{12}$	$X_2 = l_{1-4}$
1 and W 2	$p = p_{12} \cdot r_{12} - p_1 \cdot r_1 - p_2 \cdot r_2$	$X_1 = 0$	$X_2 = l_{12}$
W 2 and W 3,4	$p = p_{2-4} \cdot r_{2-4} - p_2 \cdot r_2 - p_{34} \cdot r_{34}$	$X_1 = l_1$	$X_2 = l_{1-4}$
1 and W 2 and W 3,4	$p = p_{1-4} \cdot r_{1-4} - p_{12} \cdot r_{12} - p_{2-4} \cdot r_{2-4} + p_2 \cdot r_2$	$X_1 = 0$	$X_2 = l_{1-4}$
W 2 and W 3,4 and W 5,6	$p = p_{2-6} \cdot r_{2-6} - p_{2-4} \cdot r_{2-4} - p_{3-6} \cdot r_{3-6} + p_{34} \cdot r_{34}$	$X_1 = l_1$	$X_2 = l_{1-6}$

*) to be consindered flooded for s-calculation

6. Application of Regulation 7 (c) subdivision arrangement shown in Fig.4.A.4.

Compartment or group of compartments*)	p-factor	Distances X_1 and X_2 for determination of Factor
C 2,3 and W 2	$p = p_2\ (1-r_2)$	$X_1 = l_1$ $X_2 = l_{12}$
C 2,3 and W 3,4	$p = p_3\ (1-r_3)$	$X_1 = l_{12}$ $X_2 = l_{1-3}$
C 4,5 and W 3,4	$p = p_4\ (1-r_4)$	$X_1 = l_{1-3}$ $X_2 = l_{1-4}$
1 and C 2,3 and W 2	$p=p_{12}(1-r_{12})-p_1(1-r_1)-p_2(1-r_2)$	$X_1 = 0$ $X_2 = l_{12}$
1 and C 2,3 and W 2 and W 3,4	$p=p_{1-3}(1-r_{1-3})-p_{12}(1-r_{12})-p_{23}(1-r_{23}) +p_2(1-r_2)$	$X_1 = 0$ $X_2 = l_{1-3}$
C 2,3 and C 4,5 and W 3,4	$p=p_{34}(1-r_{34})$	$X_1 = l_{12}$ $X_2 = l_{1-4}$
C 2,3 and C 4,5 and W 2 and W 3,4	$p=p_{24}(1-r_{24})-p_2(1-r_2)-p_{34}(1-r_{34})$	$X_1 = l_1$ $X_2 = l_{1-4}$
C 2,3 and C 4,5 and W 3,4 and W 5,6	$p=p_{35}(1-r_{35})-p_{34}(1-r_{34})-p_5(1-r_5)$	$X_1 = l_{12}$ $X_2 = l_{1-5}$
C 2,3 and C 4,5 and W 2 and W 3,4 and W 5,6	$p=p_{25}(1-r_{25})-p_{24}(1-r_{24})-p_{35}(1-r_{35}) +p_{34}(1-r_{34})$	$X_1 = l_1$ $X_2 = l_{1-5}$

*) to be considered flooded for s-calculation

II. Recesses (Regulation 6(a)(iii)

1. Recesses to be dealt with in accordance with Regulation 6(a)(iii). However, the provision of Regulation 7 may be applied if necessary. This will be demonstrated using the example shown in Fig.4.A.5.appended hereto.

2. The following nomenclature will be used:

l_1, l_2, l_3	as shown in Fig.4 A.5
p_1, p_2, p_3	are p calculated by formulae (IV)x), using l_1, l_2, l_3 as l
p_{12}, p_{23}	are p calculated by formulae (IV)x), using l_1+l_2 and l_2+l_3 as l
p_{123}	is p calculated by formulae (IV)x), using $l_1+l_2+l_3$ as l
r_1	is r calculated by formulae (X)x), using l_1 as l and b as shown in Fig.4 A.5
r_2	is r calculated by formulae (X)x), using l_2 as l and b as shown in Fig.4 A.5
r_{12}, r_{23}	are r calculated by formulae (X)x), using l_1+l_2 as l and b as shown in Fig.4 A.5
r_{123}	is r calculated by formulae (X)x), using $l_1+l_2+l_3$ as l and b as shown in Fig.4 A.5

x) as given in the new Regulations

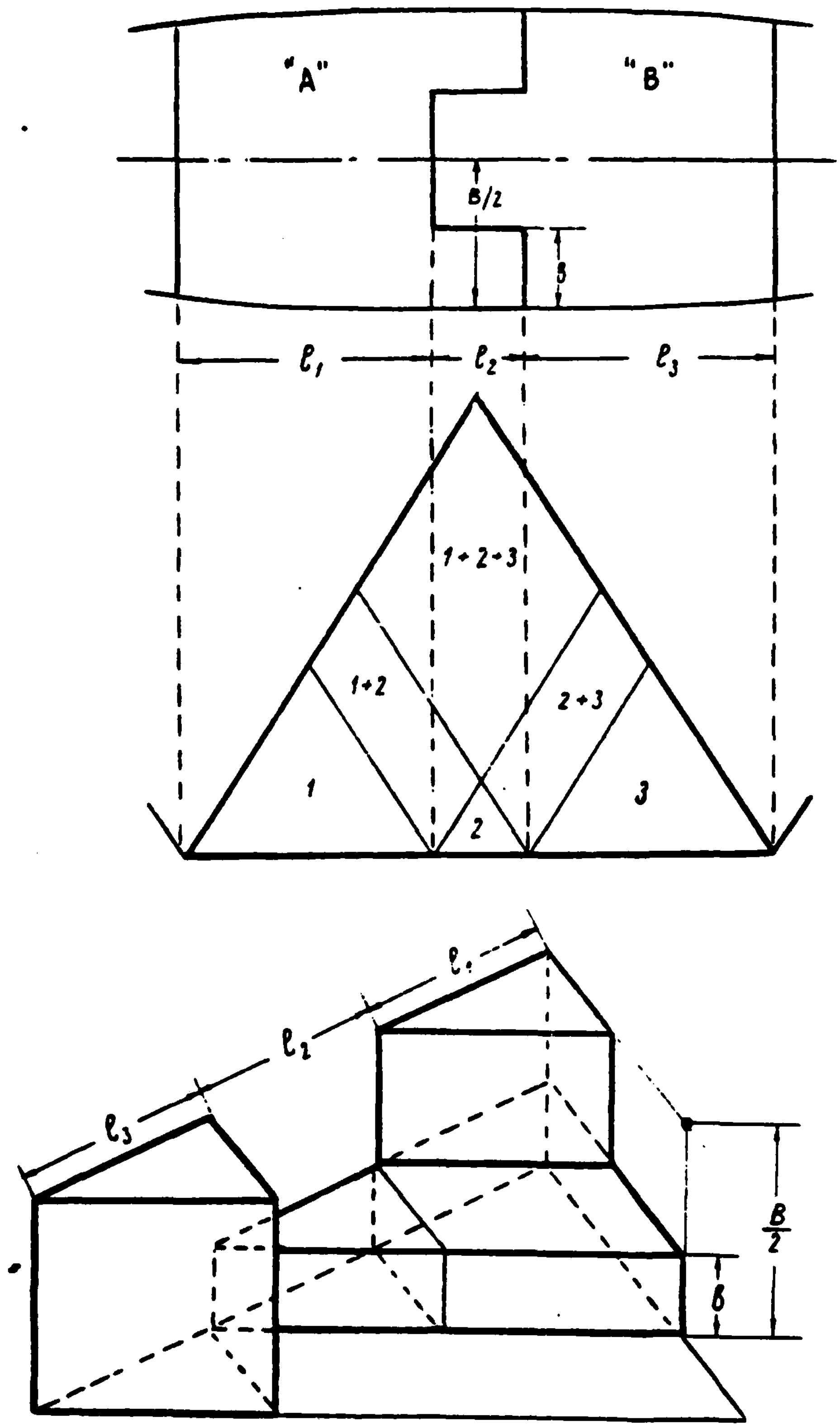

FIGURE 4.A.5

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3. Application of provisions of Regulation 6(a)(iii):

Spaces to be considered flooded for s-calculation	p-factor to be used for calculating contribution to attained subdivision index
A	$p = p_{12} r_{12}$
B	$p = p_3$
A and B	$p = p_{123} - p_{12} r_{12} - p_3$

4. Application of provisions of Regulation 7:

A	$p = p_{12} r_{12} + p_1 (1-r_1)$
B	$p = p_3$
A and B	$p = p_{123} - p_{12} r_{12} - p_1 (1-r_1) - p_3$

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